INDIAN WATER POWER PLANTS

A COMPANION VOLUME TO

HYDRO-ELECTRIC INSTALLATIONS OF INDIA

INCLUDING CHAPTERS ON

'Water-Power Projects of Burma', 'Achievements and Tendencies Abroad'.

TWENTY CHAPTERS, SIX APPENDICES, THREE DOZEN TABLES, THREE DOZEN ILLUSTRATIONS.

BY

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PREFACE

During the last decade, considerable progress has been made in the development of the hydraulic resources of India for power purposes and the time appears opportune to supplement the information published in the book entitled "*Hydro-electric Installations of India*" by the present author, in response to requests to prepare and publish a companion volume to his first book on the subject, which will be referred to later whenever necessary by the abbreviation H. E. I. I. (see 'Opinions' at the end.)

The present publication deals principally with hydro-electric plants and projects of the past dozen years or so. The introductory chapter is of a general character and designed to establish the close connection in India between Water and Electricity and their collaboration in the service of Man. In the second chapter, the history and growth of the water power plants and projects of India is traced step by step and some comparisons are drawn between the different systems and schemes described in the book. The trend of water power development in other countries and their achievements in this field are indicated in the third chapter. The subsequent chapters deal with the progress and present position of Indian hydro-electric plants in the different provinces and States of India and Burma, one by one. The twentieth chapter was intended to be devoted to Electric Railways in India, in view of the fact that one noteworthy feature of the period with which the book deals has been the utilisation of water-produced power for working the railways and tramways of Bombay and its suburbs. However, railways have not always to rely upon hydro-electric energy for tractive effort required to transport men and materials, even if electric motors are used for this purpose. Therefore the Author proposes to utilise the matter he has in his possession to publish, God willing, a separate booklet dealing solely with the subject of electric railways in this country. Supplementary notes have been collected together into one chapter at the end of the book. Moreover, a number of appendices have been added and the contents of each of them is indicated; this has also been done in the cases of Tables and Illustrations. An Index showing the numbers of the pages where individual items of interest are mentioned in the body of the book brings the volume to a close.

Hydro–electric installations are usually associated in our minds with high hills where large 'drops' or 'falls' of water can be effected conveniently owing to the natural configuration of the surrounding country, but a remarkable aspect of recent hydro-electric progress in this Peninsula has been the develop-

ment of the power from several canal-falls of less than 20 feet and the linking together of such scattered power systems into a Grid or network of electric supply in the United Provinces of Agra and Oudh. Another noteworthy feature of hydro-electric undertakings has been the greater attention paid to rural electrification of recent years, particularly by the Mysore Darbar, whose example has been followed by the Governments of the United Provinces, the Punjab and Madras. Several towns now receive bulk supply from the Tata systems in the Bombay Presidency. One more step forward deserves special mention. At long last, a beginning was to be made in the utilisation of water power for electro-chemical works in the premier Mahratta State of Kolhapur. But unfortunately little progress has so far been made. There are several industries waiting to be established in this country where Nature has provided us with useful materials and favourable situations for making chemical products after arrangements have been made for generating the necessary amounts of electric energy but economic and other considerations make the industrial march of India somewhat slow. Appendix VI deals briefly with the subject of electro-chemical industries which are likely to receive more attention in the future in this country judging from what has happened in other lands.

Most of the larger Provinces and States of India can now boast of possessing in their territories at least one water power plant, but Southern Bengal, Bihar, Orissa, Central Provinces, Sind, Central India, Baroda and Hyderabad States are still lagging behind, not having added any water power plant to the numerous electric stations in their larger cities and towns. To Bengal, however, belongs the credit of having lighted the trail or shown the way of harnessing the rivers of hills for power purposes, for the first installation of this kind in point of time is that of Darjeeling, the summer capital of the Government of Bengal. Bombay has left Bengal far behind, though the Western Presidency is not blessed with such high mountains and mighty rivers as the Eastern Presidency. Grateful acknowledgments are hereby made to all persons and papers for all their matter used in this volume by the Author, who will be glad to be informed of any inaccuracies or errors of omission or commission and suggestions for improvement by interested readers as was done in connection with his first book by some engineers, particularly by Rao Bahadur G. Sundaram.

" The Author acknowledges his indebtedness to the University of Bombay for the substantial financial help it has granted towards the cost of the publication of this work."

SHIV NARAYAN.

CONTENTS.

BY THE SAME AUTHOR.

1. Hydro-electric Installations of India;
   Royal Octavo size, 310 pages, 74 Tables, 60 Illustrations.
   ... (Quarter-cloth bound, Rs. 7/8-; paper bound, Rs. 6/8-per copy).

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4. *Indian Water Power Plants*;
   Royal Octavo size, about 200 pages, 35 Illustrations,
   38 Tables, (Cloth bound, Rs. 5/- per copy).

Obtainable from Messrs. D. B. Taraporewala, Sons and Co.,
Booksellers, Bombay; and
from Brij Narayan Esq., Power Sales Engineer,
The Poona Electric Supply Co. Ltd,
Ganeshkhind Road, Poona 5.

Booklets in Preparation.

Electric Railways in India; and
Wireless Stations in India.

OPINIONS ON MS. OF "INDIAN WATER POWER PLANTS."

Electrical Engineer to Government of Bombay (F. O. J. Roose):—

"I have gone through Prof. Shiv Narayan's manuscript with care and must congratulate him on having produced *a work of great interest to all engineers* who are in any way associated with the production of electricity by use of water power. The Author has collected in one volume an *enormous amount of data* and descriptive information concerning Hydro-electric Generation in India and he shows very clearly the enormous development of the last 10-12 years. He describes in great detail the different schemes, those whose draw-off is taken from impounded rivers, reservoirs fed by irrigation canals and reservoirs fed from the rainfall run-off from large catchment areas. He also discusses the transmission line construction of various schemes together with their transformer stations.

'Indian Water Power Plants' is a *valuable book of reference and* I wish it every success and a very wide circulation.

Principal, College of Engineering, Poona (C. Graham Smith):—

" Having looked through the Manuscript of Prof. Shiv Narayan's new book, I have no hesitation in recommending.........As far as I am aware, nothing of the sort has been published for a dozen years or so and it is desirable to bring the record up to date in as far as it is possible in a subject that is constantly under development and where progress is being constantly recorded. "

ACKNOWLEDGMENTS.

Grateful acknowledgments are hereby made to all persons and institutions who have helped the Author in collecting information and illustrations for this book. Particular mention is made of the following :—

(1) Mysore State Installation.–C. M. Cariappa, Esq., F. N. Mowdawala, Esq., S. G. Forbes, Esq., D. B. N. N. Ayyangar, Chief Engineers.
(2) Jammu and Kashmir State Installations.–L. C. Bose, Rai Bahadur, Chief Engineer, Electrical Department.
(3) Tata Water Power Plants.–B. P. Sethna, Esq., General Manager (Figs. 1 (a) and 39).
(4) Mussoorie and Naini Tal Plants.–G. Mc. C. Hoey, Esq, Superintending Engineer: K. Chattopadhya, Esq.
(5) Naini Tal Installation.–Messrs. Inder Lal Sah, A. B. Haddow and R. L. Khanna.
(6) Upper Ganges Canal Plants.–Sir W. L. Stampe, Chief Engineer and his assistants in charge of plants. Messrs. E. C. Walton, G. S. Mathur, Roorkee.
(7) Simla Water Power Plant.–R. L. Narayanan, Esq., Electrical Engineer.
(8) Annamalais District Installations.–Chief Engineer, Kanan Devan Hills Produce Co.
(9) Travancore State Water Power Project.–Electrical Engineer, Trivandrum.
(10) Madras Govt. Water Power Projects.–Major H. G. Howard, Chief Engineer for Electricity, and his assistants, F. N. Mowdawala, Esq., T. J. Mirchandani, Esq., Rao Bahadur G. Sundaram, Madras (Fig. 38).
(11) Uhl River or Mandi Installation.–H. P. Thomas, Esq., Chief Engineer to Govt. of the Punjab, Electricity Branch; S. A. Gadkary, Esq., Executive Engineer; N. V. Dorofeeff, Esq., N. B. Macmillan, Esq.
(12) Baroda State Scheme.–T. E. de Morsier, Esq., Chief Engineer.
(13) Gwalior State Scheme.–A. N. Pollard, Esq., Chief Engineer.
(14) Rewa State Sites.–S. Ghosh, Esq., State Engineer.
(15) Engineering Supplement, Times of India, Bombay.
(16) Indian Engineering, Calcutta.
(17) Indian Electrical Times, Calcutta.
(18) Capital, Calcutta.
(19) Electrical Engineering, New York.
(20) Distribution, London.
(21) Garckes' Manual of Electrical Undertaking, London.
(22) Figs. 13, 14, 16, 29, 36.–Times of India.
(23) Figs. 31, 32.–*Journal of Association of Engineers*, Calcutta.
(24) Figs. 21, 22, 23, 24, 26, 27, 28, 33, 37.–Electrotechnics, Bangalore.
(25) R. B. Venkatesh Krishna Iyer, Ex. En., Mettur Dam.
(26) Fig. 36a–Diploma Classes Magazine, College of Engineering, Poona.

PARTICULARS OF TABLES

TITLES OF ILLUSTRATIONS

DEDICATION

To you, dear Parents mine!
You who bore names divine,
That imply **Water, Power!**
You in your lives did shower
Good deeds on friend and foe.
You left us long ago:
But that you're not forgotten,
This book is but one token.

S. N.

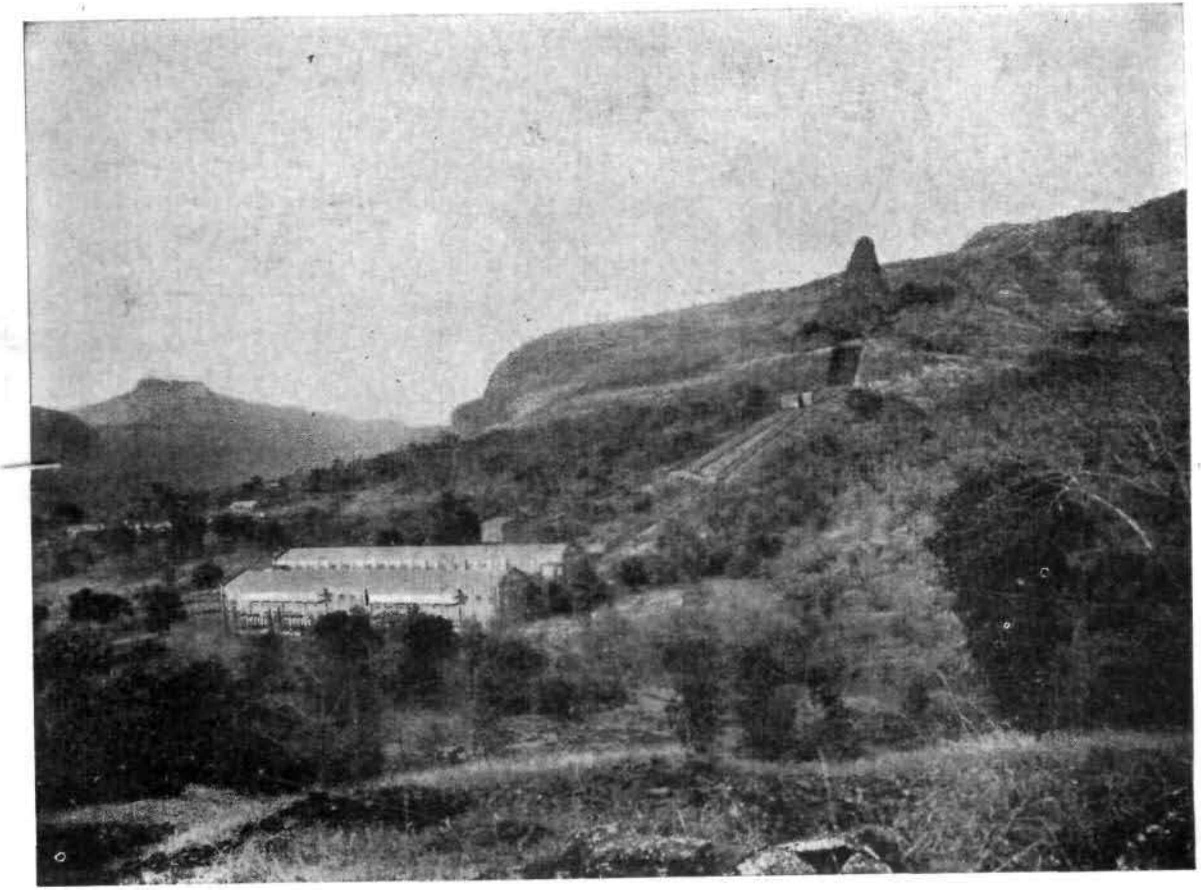

Fig. 1 (a). *Water* Pipe Line and *Electricity* Power House, BHIRA.

CHAPTER I

INTRODUCTION

WATER AND ELECTRICITY

(THE NOBLE PAIR OF MOBILE POWERS)

In Collaboration for the Service of India.*

The uses of Water and Electricity for the daily needs of civilised mankind are well-known to all educated people. Without Water, no man, woman or child could live long. Without Electricity, civilised Man would but exist. What he needs however is not merely to be able to drag out a drab existence but to live a noble life, a good life, a happy life. Surely the present generation, who are called by Tennyson 'the heirs of all the ages', cannot be expected to remain aloof from the world or untouched by the breath of Progress. They will not consent to forego the advantages and improvements which have been made possible for them by the advance of Man throughout the ages from the state of a savage to that of a civilised being. Not only the privileged few who reside in large centres of population but the many people who live in small towns and villages which form the vast majority of this sub-continent must in increasing numbers be affected by the tide of the Times and crave for amenities of life which have hitherto been denied to them or remained unknown to them. On all sides there is a recognition of the claim put forward on their behalf that they should be allowed to share in as many good things as are essential to life and that they should not be kept in utter darkness and utmost dearth of the appliances and works which have been invented or devised in order to ensure health, shelter and occupation and to provide means of subsistence, cultivation and instruction. Pure water and good light are two of the principal desiderata of the Indian countryside.

It is true that Nature has endowed the farmers with a bountiful supply of fresh Air, but for the provision of good Light and pure Water which are equally necessary, Art must be invited to assist

* This Chapter was sent to the Editor, *Indian Electrical Times*, Calcutta in response to his request and appeared as the first article of the first number of that Magazine. *S. N.*

Nature. This is where the Engineer comes in. Engineers who feel enthusiastic about promoting the welfare of their backward brethren in the villages should offer their services to those undertaking schemes for rural reconstruction. The introduction of cottage industries, vernacular newspapers, cinema lectures and wireless receivers — among other novelties — has been advocated in public and in private. For all these innovations, engineers would prove of great use and assistance. In order to supply pure water, effect good drainage, establish printing presses, instal pumps, looms, gins, radio sets and cinema projectors, the assistance of electric power is, wherever possible, invoked and utilised. Educated young men, who have specialised in one or other of the professions which are calculated to be of use in building up the nation — for example, teaching, medicine, sanitation, mechanical and electrical engineering with the subsidiary subjects of illumination, plumbing, carpentry, smithy, machine work for repair of textile machinery, cottage industries, wiring, radio etc.— should resolve to spend their lives among or near the people of the villages and for the purpose of bringing about their improvement and advancement. The force of circumstances or the trend of present-day economic influences is bound sooner or later to cause a migration of the educated from the cities where they received their instruction and training to the fields and hamlets where the vast numbers of people, of what is pre-eminently an agricultural country, must perforce have their habitations. Since the above was written, a similar sentiment has been well expressed by the present Governor of Bombay, Lord Brabourne, in these words,—'nothing is more urgently required in rural areas than the presence of men with new ideas and the will to make a success of them.' Although the countryside needs teachers and doctors as well as engineers, we are here concerned only with the activities of the latter in so far as they are related to the supply of water and electricity.

Hydro-electric installations are usually situated in out-of-the-way places and those connected with them have naturally to spend a part of their time away from towns and cities. Resident engineers and operators dwelling among the country folk soon grow to know them and their mode of living and to sympathise with them. Although often started with the primary object of supplying power required by large industrial or commercial towns and big cities, hydro-electric undertakings are usually ready, when the time arrives for doing so, to incur expenditure upon extensions which would enable them to serve mankind in scattered areas of population. More and more attention has been and is being paid of recent years to rural electrification and several instances

could be cited of localities where electric supply lines have been introduced within the past few years with the aim and object of bringing electricity to the doors and fields of the village people.

The Mysore Darbar — the first administration in India to launch a large-scale hydro-electric enterprise — started the Cauvery Power Scheme in the year 1902 with the main intention of sending electrical energy to the distant Kolar Field Gold Mining Companies; but of late the Mysore Darbar has been catering more and more for the needs and wants of the countryside by extending the network of electric stations and lines throughout the State. Numerous towns and villages have been and are being wired up and served from one or other of the stations, large or small, which receive electricity supply for distribution purposes from the Central Generating Station at Sivasamudram, viz. Kankanhalli, Bangalore, Mysore and Oorgaum. The total capital invested in rural electrification schemes up to the end of June 1933 came to a little over 19 lakhs and 2 thousands of rupees. The total number of power and of lighting installations, excluding those of the Gold Mining Companies, was 2200 and 19312 as against 1763 and 16761 respectively for the previous year i. e. to the end of June 1932, *vide Engineering Supplement*, *Times of India*, Oct. 14, 1933. Likewise the number of street lights rose from 10149 to 10776. These figures bear eloquent testimony to the progressive policy of the Darbar, who have facilitated the steady growth of the Cauvery Power Installation in all directions involving the extension of the transmission and distribution systems for utilising the services of Electricity for the common good of the largest number possible of the subjects of the State.

Side by side with the spread of the electric distribution networks, the Mysore Darbar have carried out schemes for water-supply to places where need for it was acutely felt. The most notable instance of this is the new water-supply scheme of Bangalore, costing 52 lakhs and involving the construction of a 110-foot high masonry dam. Electric mains go out from the Bangalore Electric Receiving Station to the Soldevanhalli Pumping Station on one side and on the other side to Thippa-gordhanhalli Pumping Station which is also fed from the Electricity Receiving Station at Kankanhalli *via* Closepet and which supplies water to Bangalore. Recently the latter station proved inadequate because of leakage of water from the reservoir caused by the floods scouring the temporary waste-weir. A permanent waste-weir, 70′ high and 140′ wide, has been built at the cost of about 8 lakhs. The amount of Rs. 52 lakhs just mentioned includes the cost of

dam as well as waste-weir for the Bangalore Water Supply Works. Four sluice gates, each $20' \times 10'$, are to be worked by electric power.

Several other smaller towns are also utilising electric power to work pumps for their water-supply. About 300 irrigation pumps are being run electrically throughout the State territory. Irrigation proper is also to be extended. One scheme is for the construction of a dam across the Kabbini, a tributary of the Cauvery River, to irrigate 40000 acres besides supplying half the quantity of water required for power generation purposes at Sivasamudram. Another scheme is for opening out a new channel on the left bank of the Mandagere anicut to irrigate 4000 acres. To ensure a supply of at least 1200 cubic feet of water per second to the supply channel of the Sivasamudram Installation, some years back a big reservoir was created at Kannambaddi across the Cauvery. No electric power is being however as yet generated at the site of the Krishna Raja Sagara Dam, although it has been pierced with pipes at the base for future installation of hydraulic turbines and electric generators at Kannambaddi, now often referred to as Krishna Raja Sagar.

In another Indian State, an installation exists wherein occurs the uncommon combination of irrigation, electricity and water-supply. The reference is to the Jammu Hydro-electric Installation. The Ranbir Irrigation Canal of the Chenab River is the source of water for the Jammu Installation, which utilises a fall of about 26 feet and can generate up to 1070 kilowatts; but out of the four sets installed only three at the most can be run at a time as the canal supply is limited:—the maximum load recorded was 500 kilowatts according to the Return compiled for the period ending 31st August 1933 by the Chief Engineer, Elec. & Mech. Departments of Jammu and Kashmir State. In 1917, a Paterson Filter was installed at the Jammu Water Works Pumping Station, where 3000-volt motors run pumps for high-lift, low-lift and wash water. Other motor-driven pumps are installed in Pratap Bagh and elsewhere. From the water-works which are situated at the bank of the Tawi River, the water is raised to the level of the town, 335 feet.

The Amritsar Hydro-electric Installation utilised the very low fall of 6 to 10 feet to generate power up to 525 kW., a portion of which was used to work pumps that raised the subsoil water through tube-wells to ground level. For further details, the interested reader may consult the present writer's book on *Hydro-Electric Installations of India*. The most remarkable hydro-electric development as far as harnessing of canal falls for power purposes is

concerned is that of the Upper Ganges Canal in the United Provinces (where the Canal Hydro-electric Works Dept.—abbreviated as Hydel—forms a part or branch of the Irrigation Department for administrative purposes) though the hydro-electric supply of the hill-stations of Mussoorie and Naini Tal is under the purview of the Department of Public Health, the actual administration of the latter two being however under their respective municipalities.

There are 26 falls on the Upper Ganges Canal. Half the number can be utilised for power generation. Four have been so far harnessed, namely those at Bahadrabad, Bhola, Palra and Sumera. For convenience in irrigating the land to be cultivated low falls at short intervals are preferable; but from the point of view of power-generation, it is better to have a large fall because power developed depends upon the product of 'head' and 'quantity of water.' Two small falls existed on the canal in the vicinity of Bahadrabad. For the new Power Station at Bahadrabad, these two falls were merged into a single fall of about 20 feet by regrading the canal by raising the upstream piers. The new station is built over what was formerly the Salempur Fall, 2600 feet below the Bahadrabad Fall, but is known after the latter place, as the original installation (described in *Hydro-Electric Installations of India*) was put up at Bahadrabad which is situated between Hardwar and Roorkee. The Bahadrabad station is the largest of the stations so far put up on the Canal. The four stations are linked together electrically and form a Grid or Ring of electric mains to serve a large area from one or other of the canal stations and ensure continuity of electric supply to the consumers whose number has been steadily rising. An oil-engine plant not far from the hydro-electric station is put up to serve as a reserve when the output of the water-power station is found to be inadequate to meet the demand for power. It is worth making a special mention of the fact that a large quantity of water, at the rate of 100 cubic feet per second, is now being lifted by electrically-driven pumps from the Kalinadi river to irrigate an additional area of 30000 acres. The water-supply of Hardwar city as well as its electricity-supply is dependent upon the Bahadrabad Hydro-electric Installation. The same applies to a certain extent to Roorkee.

Meerut water-supply scheme is however unique in as much as water turbines were employed for driving pumps at Bhola long before the present hydro-electric installation at Bhola Falls near Meerut was put up in 1931. On other falls of this canal, water-shot wheels have been in use for several years for the purposes of driving grindstones for making flour etc.

Other places in the United Provinces of Agra and Oudh where water-supply machinery is run by electric motors are Agra, Aligarh, Allahabad, Benares, Fyzabad, Lucknow, Mussoorie, Muttra and Naini Tal. Of these, Mussoorie and Naini Tal are hydro-electric Stations of the high-head type, being situated in the Himalayan Ranges. The heads for Mussoorie and Naini Tal are respectively 1000 and 1500 feet. On the other hand, the capacity of the former station is much greater than that of the latter,-3000 kW. and 800 kW respectively. Moreover, Mussoorie has a Diesel engine plant of 960 kW to supplement the output of the hydro-electric station when the peak load comes on and transcends the limit of the water-power plant. The average loads for 1932–33 for the Mussoorie, Naini Tal and Hardwar systems were as follows:—898 (hydro) and 172 (diesel); 158 and 75 kilowatts respectively,—these figures being taken from copies of the Reports kindly supplied by the Superintending Engineer, Public Health Department, United Provinces. The figures for the capacity of the Mussoorie Hydro and Diesel stations have however been culled from '*Distribution of Electricity*' for Jan. 1933.

Facts and figures have been given above at length about one Indian State and one Indian Province. In other States and provinces of India, similar instances on different scales would perhaps be forthcoming; but it is not necessary to multiply cases of the same kind as the object of showing the close connection between Water and Electricity for mutual assistance in the service of Man has been served. No mention has however been made of a hydro-electric installation incorporated in an irrigation Dam. Such an Installation exists at Bhatghar near Bhor where the Dam across the Yelwandi River stands 190 ft. high to supply water to the Nira Canal works, the Yelwandi being a tributary of the Nira River. The hydro-electric installation at the base of the Dam provided power for the construction of the new Dam known as Lloyd Dam though more often called Bhatghar Dam. Some other high dams in the Bombay Presidency and in other States and provinces have also been designed for hydro-electric installations working alongside them; but nowhere except at Bhatghar is power being actually generated. Bombay is thus unique in this regard.

Enough has been said to show that there are many situations where irrigation and hydro-electrics may go hand in hand for mutual profit rather than operate to each other's detriment. The same source of water may be utilised for both of these purposes besides being used for the ordinary purposes of drinking and washing. Electricity may in its turn provide power for water-supply, drainage and

irrigation, besides being used for the usual work of lighting lamps and driving machines.

Fig. 1 showing the water power plants of India may be seen in my book entitled 'Hydro-Electric Installations of India': but as its contents were not mentioned there in detail, this is now being done, with necessary remarks and notes, to make it useful to readers of the present volume.

Reading from left to right and from top to bottom of the Map, it shows the provinces and plants as stated below in separate columns:—

TABLE No. 1.

Province or State.	Plant or installation.	Remarks.
Afghanistan	K–Kabul	
N. W. F. Province	Md–Malakand	
Kashmir State	Jd–Jhelum development	
	Ju–Jammu "	
The Panjab	Dl–Dhariwal ....)	Now supplied by Uhl River system
	Ar–Amritsar ....)	
	Sj–Sutlej	Abandoned
	Sa–Simla	
	P–Patiala State	Aided by Diesel plant
United Provinces U. P.	Me–Mussoorie	
	Nl–Naini Tal, to east of Me	Not shown
	Gs–Ganges canal	Now 4 plants
Nepal	Ku–Khatmandu; Pg–Phurping	
Bengal Presidency	Dg–Darjeeling	
Central India (C. I.)	Gr–Gwalior; Da–Datia	Not working
Central Provinces C. P.	Cha–Chhindwara	Pench River project
Bombay Presidency	NM–Nila-Mula (Bhira)	By–Bombay
	Br–Bhatghar	
	Sra–Satara, near Br	Not shown
	Ka–Koyna, not taken up	
	May stand for Kolhapur	(still-born)
	Gk–Gokak	
Mysore State	Ga–Gersoppa	Not started
	Cy–Cauvery	
Madras Presidency	Kb–Kundah	Abandoned
	Replaced by Pykara	Pa–completed
	Ce–Cordite (factory)	
	Pr–Periyar	To be started
Travancore State	Pl–Pallivassal	Started

N. B. Mandi (Uhl River) in the Panjab, Mettur Dam in Madras Presidency and Maymyo in Burma, not shown in the Map, have materialised recently.

CHAPTER II

HISTORY AND GROWTH OF WATER POWER PLANTS OF INDIA.

The past few years have witnessed considerable activity on the part of several administrations in India in the development of their water-power resources and the time seems opportune for dealing with the History of Hydro-electric Enterprise in this country. Other engineers have read papers about similar All-India themes before the Institution of Engineers (India). I have particularly in mind the paper on "Irrigation in India by Mr. D. G. Harris, published in the Journal of this Institution for April 1923. I have thought of this Paper because irrigation and water-power are a pair often found collaborating for mutual improvement and profit. Since the account is to be one of 'growth,' the title 'Plants' is used here in preference to 'Installations' which was adopted by me for my book on '*Hydro-Electric Installations of India,*' references to which in the present publication will be indicated by the letters 'H. E. I. I.' to avoid unnecessary repetition of facts and figures already published in that book. ‡

Subsequent to the publication of 'H. E. I. I.,' articles about water-power plants and projects have appeared in the Press and Technical Magazines from time to time, but they are scattered and not easily obtainable for ready reference. I am not however aware of a Paper or Book wherein up-to-date data about all such projects and plants have been published.

This chapter deals with the gradual growth of the various Water Power Plants in India, in a chronological order. Different stages of growth have therefore been mentioned in different places, as the subject is divided into periods of time. A coherent idea of the steady growth of individual installations can however be got from the data incorporated in the First Appendix which treats of one plant at a time and shows its rise at a glance. The same purpose is served by the Graph showing Growth of Indian Water Power Plants, see Fig. 2.

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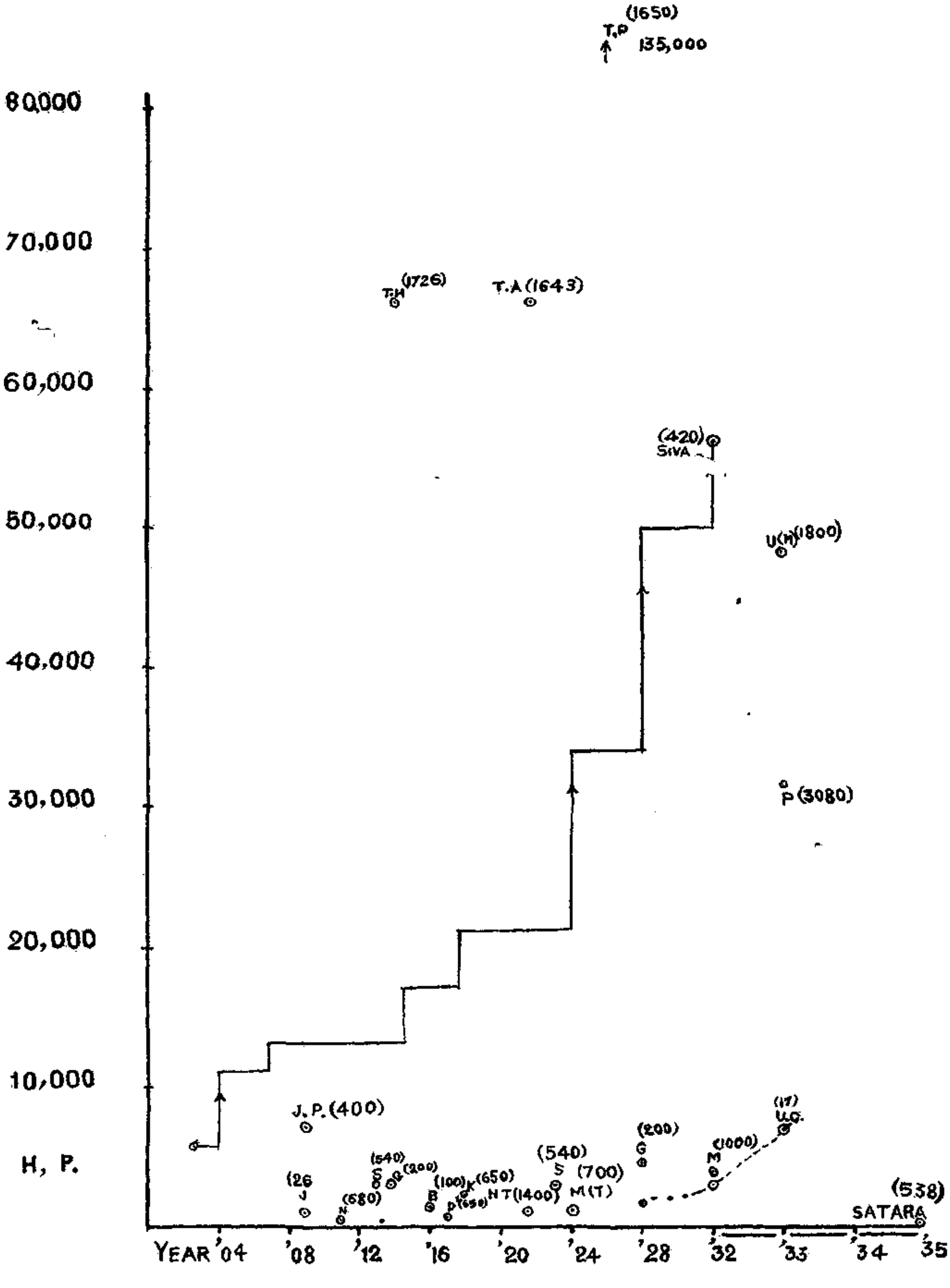
‡ Obtainable from Messrs. Taraporewala, Sons and Co., Booksellers, Hornby Road, Bombay.

N. B. The first 9 pages of this chapter appeared as an article in the Annual Industries Supplement of *Capital*, Calcutta for Dec. 1934. The portion headed 'Which is the First?' appeared as an article in the first number of Radio, Talkie and Electrical News, Bombay, in response to the Editor's request.



↑—SIVASAMUDRAM, T. H.—TATA HYDRO, T. A.—TATA ANDHRA, T. P.—TATA POWER, P—PYKARA, K—KATERI, G—GOKAK, B—BHATGHAR, M—MUSSOORIE, U—(M).—UHL RIVER (MANDI), U. G.—UPPER GANGES, D—DARJEELING, S—SIMLA, J. P.—JHELUM POWER, J—JAMMU, M (T)—MUNNAR (TRAVANCORE), N—NEPAL (KHATMANDU), N T—NAINITAL

N. B.—Figures within brackets indicate 'Head' in feet

Fig 2. GROWTH OF INDIAN WATER POWER PLANTS.

(TO FACE PAGE 8)

Five Periods.

The narrative of the advancement made in matters hydro-electrical throughout the length and breadth of the Peninsula of India may conveniently be divided into five periods, each a decade with the exception of the first. These periods are as follows:— (a) Prior to 1900, (b) 1901 to 1910, (c) 1911 to 1920, (d) 1921 to 1930, and (e) 1931 to 1940.

(a) Prior to 1900.

Non-electrical water-power plants of comparatively low falls and low outputs existed, prior to the commencement of the twentieth century, on some of the large canals in North India and large estates in South India. Water power plants of somewhat larger capacity, what we may call medium capacity, had been put up at Ambasamudram and at Gokak in the Presidencies of Madras and Bombay respectively. At the former place, Messrs. Harvey Brothers utilised the Papanasam Falls of the Tambrapani River to provide power required for their mills. The falls are 250 feet high and are situated at a distance of 22 miles from Tinnevelly and 54 miles from Tuticorin. As for the second water-power plant just referred to, the reader who is interested in the rise of the Gokak Falls Installation would do well to turn to Chapter VII of H. E. I. I. where, on page 121, Fig. 28 shows the plant in the transition stage, with the transmission cables on the left, the ropes they replaced on the right, the Falls between the two and the rocky hills behind. The original Gokak Plant was erected as far back as 1886. Water-driven turbines still exist at Bhola pumping station for the water supply of Meerut, 9 miles from Bhola where there is a fall in the Ganges Canal.

The first electrical water-power plant was set to work in 1897 at Darjeeling.* In 1898, the Darjeeling power house was flooded and the governor smashed owing to a cyclone (H. E. I. I. page 150). The necessary repairs were carried out in a couple of months.

(b) 1901 to 1910.

Though thought of about the same time as the year in which the Darjeeling plant started to give supply, the Cauvery Power Scheme of Mysore State did not fructify till 1902, when the first

* See H. E. I. I. Chapter X, particularly pages 148 to 151, Chap. XVIII page 247 Table 47, page 251 Table 52 and page 254 Table 57.

installation was taken in hand at Sivasamudram not far from the Waterfalls. This plant was soon after able to produce 7500 b. h. p., and electric energy was transmitted 92 miles to the Kolar Gold Fields at a pressure of 35000 volts. Compared with this, the original Darjeeling plant was a pigmy, its maximum power being 400 h. p., voltage 2330 volts and transmission distance about 2 miles only. It is not to be wondered at, therefore, that the Indian Industrial Commission committed the mistake of stating in their Report that 'the Mysore Durbar set up the first central hydro-electric installation in India.' For information and illustrations relating to the Cauvery Falls Scheme, the reader is referred to H. E. I. I., Chap. IX. It is curious to note that neither the Darjeeling nor the Sivasamudram Installation employed the standard British periodicity of 50 periods per second for the alternating current transmitted; the former using a frequency of 83·3 and the latter of 25 cycles per second. Twenty-five cycles is at least recognised as a secondary standard by the British Engineering Standards Committee, but 83·3 is so uncommon that it is difficult to think of stations where it is used. Mr. J. W. Meares who started the Darjeeling station as a municipal concern, realised in later years when he rose to be the Electrical Adviser to the Govt. of India that "it is very desirable in the interests of British Trade that British standards of pressure and frequency should be adopted in all future hydro-electric work and the suggestion is put forward that this should be a condition of all leases and agreements for the development of water power." This quotation is from page 31 of the Preliminary Report on the Water Power Resources of India (abbreviated as P. R. W. P. R. in H. E. I. I.). The pros and cons of 25 cycles and 50 (or 60) cycles were discussed at length by Mr. S.G. Forbes and Mr. A. L. Stanton in the Journals of the Institution of Engineers (India) for 1922 and 1923 respectively. The original Kottagudi Power House in the Annamalais was erected in 1900 or thereabout.

The first Government hydro-electric installation in British India was started in 1904 for the purpose of providing power for the Govt. of India Ordnance Dept. Cordite Factory at Aruvankadu in the Nilgiri Hills of South India. A brief description of this Installation near the Karteri Falls will be found on pages 166 and 167 of H. E. I. I.

In 1904, the Cauvery Falls Installation was extended by the erection of five units similar to the six installed in 1902, bringing the capacity of the station to about 11000 e. h. p. (13,750 b. h. p.). In 1906, a double-circuit 35000-volt line was run to Bangalore. The

third Installation at Sivasamudram increased its capacity in 1907 by a 2000 e. h. p. generating unit and included also the completion of the 22,000–volt line to Mysore.

In 1906, the Munnar River was harnessed for power by the Kanan Devan Hills Produce Co. of South India, by creating an effective head of 400 ft. (see H. E. I. I., page 187). The present 'Head' is 700 ft., see Appendices I, II and Chapter XVIII.

In Sept. 1905, the Govt. of India issued a circular letter to Local Governments enquiring as to possible sites where water-power may be developed (P. R. W. P. R.)

The Tata Syndicate was granted a license by the Govt. of India in 1907 to supply hydro-electric energy to Bombay and the Tata Hydro-electric Power Supply Company was registered in November 1910.

In 1905, the Govt. of Kashmir invited Major A. J. deLotbiniere R. E. from Mysore to advise as to the ways and means for providing power to dredge the bed of the Jhelum River a few miles below Baramula and to give electric supply to Srinagar. The Jhelum Power Installation at Mohora was inaugurated in 1908 and electricity was supplied early in 1909 to Srinagar for lighting the city and working the silk factory and to Baramula for operating the dredgers. Details of this Installation are to be found in H. E. I. I., Chap. III. The frequency used here is 25 cycles per second, the plant having been supplied by the G. E. Co., U. S. A., the same company that got the contract for the Cauvery Falls Installation. A hydro-electric installation for the winter capital of the Jammu and Kashmir State at Jammu was put up in 1909 and the Palace lighting finished in 1912–13 (see Chapter IV of H. E. I. I.). This is a canal-fall Installation.

In 1909, one more hydro-electric plant was put up at Govt. expense in North India, viz. the one at Mussoorie in the Himalayas (see H. E. I. I. page 171).

(c) 1911 to 1920.

Since 1910, a high-head hydro-electric plant utilising natural springs at Phurping to develop 780 h. p. has been in operation and a new plant has been put up in 1935 at Sundarijal in Nepal State, about 10 miles from Khatmandu near Raxaul, the rail terminus (see H. E. I. I., pages 185 and 186). In 1911, the Irrigation Dept.

Power Installation on the canal near Amritsar started functioning (see H. E. I. I., page 175).

In 1913, the Simla Municipality put up a water-power plant which is described in Chapter XI of H. E. I. I.: in the same year, the Gokak Falls Installation was altered into a hydro-electric medium-pressure installation, medium in both the hydraulic and the electric senses (see H. E. I. I., Chap. VII).

In 1912, the Krishnarajasagara Cauvery Reservoir Scheme (see H. E. I. I., page 135) was taken in hand with a view to ensure constant delivery of water required to produce sufficient power at Sivasamudram which was able to give 14,650 e. h. p. The maximum load on that system was however 15,300 e. h. p. Installation No. IV was therefore undertaken and finished in 1914. Two 2000 e. h. p. sets were installed and the Kolar-line voltage was increased to 75,000 volts. Installation No. V brought up the capacity of the station to 21,000 e. h. p. by the erection of the first high-head reaction turbine in India, in the year 1917. The new Receiving Station at Bangalore was ready in 1920.

The old Kottagudi D. C. plant was replaced by a better D. C. plant in 1912-13.

In 1914, the Mohora Installation began to give electricity supply to the town of Baramula, in 1917 to Gulmarg and in 1918 to Doabgah and Sopore in Kashmir.

In 1914-15, the Bombay P. W. D. worked the Bhatghar Installation to provide power for the machinery used in connection with the construction of the Lloyd Dam at Bhatghar (see H. E. I. I., Chap. VIII).

One oil-cooled 120 kVA transformer was installed at the Kateri Falls Installation in 1914 and two 250 kVA transformers in 1917 (see H. E. I. I., page 167).

The second installation or the Upper Plant at Darjeeling was put up in 1916-17 (see H. E. I. I., page 147).

The Annally Power Station in the Annamalais S. I. was erected in 1915.

The first Installation at Bahadrabad near Hardwar was completed in 1917 and particulars of it are given on pages 168 and 169 of 'H. E. I. I.'

The small Malakand Water-power Plant started giving supply in 1919 (see Chap. XII of H. E. I. I.).

The foundation-stone of the Tata Hydro-electric works was laid at Lonavla on Feb. 8, 1911 and the whole of the power expected to be made available was applied for before Aug. 1, 1911. The Khopoli Power Station was completed in 1914 and power from it was introduced in Bombay Mills in Feb. 1915.

Detailed descriptions and illustrations of full-page size of the Tata Hydro-electric Schemes will be found in H. E. I. I., Chapters V and VI. The appendix to H. E. I. I. on pages 292–296 reproduces the Andhra Valley Hydro-electric License, sanctioned by the Governor in Council on the 3rd of April 1919 in favour of the Tata H. E. P. S. Co. The Andhra Valley Power Supply Company was registered on the 31st of August 1919. A general survey of its works was published in the Journal of Institution of Engineers (India) for April 1923; for electrical data, see Table No. 14 Chapter VI. Sir Dorab Tata was one of the members of the Indian Industrial Commission, 1916–18, whose president Sir Thomas Holland was influential in the inauguration of the Institution of Engineers (India). The Commission "urgently enjoined (the Government) to undertake a hydrographic survey (of India) in order to determine the places which offer possibilities for the establishment of hydro-electric installations." The Hydro-electric Survey of India was created as a result of this recommendation. The Chief Engineer and Electrical Adviser toured the country, collected materials and published three reports which, it is curious to note, were issued in volumes of three different sizes in 1919, 1920 and 1921 respectively. In Oct. 1920, the Govt. of India decided that "all outlay on water storage and water power will be Provincial charge and the necessary provision for hydro-electric surveys should be made in the Provincial estimates from and after the year 1921–22."

(d) 1921 to 1930.

The Report on Bhakra Dam across the Sutlej River, from which 200,000 e. h. p. was expected, (*vide* H. E. I. I., page 172) was published in 1921. Later, the Government decided to postpone this project. The Uhl River site in Mandi State was investigated in 1922 and a Report on it printed in 1923. The carrying out of the Mandi Scheme was sanctioned in 1925 and work begun in 1926.

About this time was completed the Bhandar-dara Dam across the Pravara River in the Bombay Presidency. This is no less than 270 ft. high and was expected to provide 4570 h. p. (*vide* H. E. I. I., page 287), but has not been utilised for power generation in spite of

the high head available on the spot without involving further expenditure, beyond what has already been incurred, on the hydraulic side. Penstocks have been provided at the base of the Dam, but no turbines have been installed. On the 8th of August 1921, the Govt. of Bombay decided to discontinue forthwith the Hydro-electric Survey in the Presidency and to send back two engineers imported for the Survey to assist the permanent engineer in charge of it.

Electricity from the Andhra Valley Co.'s Power Station at Bhivpuri near Karjat was sent to Bombay in Oct 1922 and from the Tata Power Co.'s station at Bhira in Mangaon Taluka of Kolaba District, in April 1927. Hydraulic and Electrical Data of all the Tata works and stations are given in Appendices I and II at the end of Chapter VI, the particulars having been kindly supplied by the General Manager. About the end of the year 1922, the Naini Tal Hydro-electric Installation put up by the Govt. of U. P. Public Health Dept. was handed over to the Municipality and started working with three 150 kW. sets, the head being about 1500 feet.

The Pykara Hydro-electric Scheme of Madras Presidency was investigated from 1921 onwards and its construction was sanctioned by Government in Oct. 1929. Eighty per cent of Pykara power will be consumed in the textile, cement, tea and cottage industries and for pumping.

The Pannimade Power House of the Tea Estates Co. of the Annamalais of South India was constructed in 1923-24.

The Mohora Power transmission system was extended to Pattan in 1929.

In 1924-25, 1926-27 and 1928, the Bombay Electric Supply and Tramways Co. installed high-voltage transformers to receive bulk supply from the Tata group. In 1928, the Bombay Suburban Electric Supply Co. began to take electrical energy in bulk from the Andhra Valley Co. of the same group, and the Thana Electric Supply Co. from the Tata Power Co. In 1929, the Lonavla-Khandala E. S. Co. and the Kalyan E. S. Co. obtained bulk supply from Tata Power Co. In 1930, the Panvel Taluka Development Co. received bulk supply from the same company of the Tata group. Further particulars of all companies receiving bulk supply of electrical energy from the three Tata Hydro-electric stations are to be found in Table No. 15 of Chapter VI.

Installation No. VI of the Cauvery Power Scheme was carried out in 1924, when the eleven 1250 b. h. p. impulse turbines were

scrapped and in their place six more 5600 b. h. p. reaction turbines similar to the one installed during the preceding decennium were erected at Sivasamudram, the gross head being thereby increased from 406 to 424 feet, by the draft-tube effect. The installation was thus able to provide 34,000 e. h. p. utilising 900 cusecs, a constant discharge of this amount being assured by the completion of the Krishnarajasagara Dam, 80 ft. high with 11,000 million cubic feet of water stored behind it. In 1928, the capacity of this plant was further augmented by the addition of two 9000 b. h. p. turbines. Installation No. VII is therefore good for about 65,000 b. h. p. or 50,000 e. h. p. the corresponding quantity of water used per second being 1200 cubic feet. In 1929, the Mysore Installation supplied electric power to the Mettur Dam works, 60 miles away at 37500 volts, to assist the Madras Government to build the big dam across the Cauvery river. The plant then comprised two 7050 kVA, seven 3530 kVA and three 1765 kVA alternators.

In 1930, two of the Ganges Canal Installations, viz. those at Bhola and Palra Falls, were in a position to supply power to Meerut (see H. E. I. I. page 171) and to Khurja etc. respectively. About the same time, the new Bahadarabad station was constructed right across the same canal at Salempur, to deal with a larger quantity of water: the old station was not built over the main fall of the canal, but across a by-pass channel on separate foundations. (See details on pages 168 and 169 of H. E. I. I.)

(e) 1931 to 1940.

The present plant of the Mussoorie undertaking was put up in 1932. The enlarged Bahadarabad installation was opened for supply of power in March 1932. About the same time, the fourth station of the Upper Ganges Canal Hydro-electric Scheme (referred to as Hydel for the sake of brevity by U. P. officials and engineers) was completed at Sumera, 15 miles lower down on the canal than the Palra plant which it resembles in many ways. All the Ganges Canal Installations are tied together electrically and supply power to the U. P. Grid which is spread over a very large area (exceeding 10,000 sq. miles) extending from Hardwar in the North to Agra in the South and from Chhaprauli in the West to Moradabad in the East. There are 13 falls on the Canal ; other installations will be put up when the demand in their vicinity increases and they too will be tied to the Grid.

In 1931, the Poona Electric Supply Co. began to take bulk supply of electrical energy from the Tata Power Co. through the lines from

the power station of the sister company at Khopoli. The D. C. plant at Kottagudi was replaced by an A. C. plant in 1932.

In 1932, the same Tata concern began to supply power in bulk to the Bhiwandi Electric Supply Co. near Kalyan.

In April 1932 the tunnel, 14200 ft. long and 9 ft. 3 in. in diameter through the 9000 ft.-high Dhauladhar range of the Himalayas separating the valleys of the Uhl and Rana rivers, was completed and enabled power from the Mandi Scheme generating station at Jogindranagar to be transmitted to the capital of the Punjab, Lahore; the inauguration of the Shalamar Receiving Station taking place at the hands of the Viceroy on the 10th of March 1933. Further details and particulars of the Uhl River Scheme will be found in the Appendices and in Chapter XIII.

The eighth Sivasamudram installation of 1933-1934 replaced one 1500 kW set by a 6000 kW set, bringing the installed plant capacity up to 42000 kW or 56000 E. H. P.

The construction of the works required to put into effect the Pykara Power Project of Madras Presidency was commenced in 1930, the main contractors for the plant and transmission line being the Power Securities Corporation Ltd. The first stage of this scheme was formally declared completed by the Governor of Madras on Apr. 5, 1933. Hydraulic and electric data will be found in Appendices I and II and in Chapter XV of this Book.

Another hydro-electric plant of Madras Government which will perhaps be ready in 1937 is that incorporated with the great cement-concrete Dam at Mettur across the Cauvery River. This dam has been pierced with four culverts, 8ft. 6in. in diameter each, for the penstocks leading to the water-turbines. The Mettur Dam is 5300ft. long and 176 ft. high: a head of 125 ft. will be utilised for the development of power up to 33000 h. p. It will put Lake Whiting of the Bhatghar Dam which stores 24,198 million cu. ft. (H. E. I. I., page 131) in the background, as it will store no less than 90,000 million cu. ft. behind it.

In 1933, the Govt. of Travancore sanctioned the Pallivassal Scheme for the harnessing of the Munnar river in North Travancore to provide power to Alwaye, Kottayam, Alleppey and other places in the State. 10,000 kVA will be generated without involving any arrangements for the storage of water when a tunnel, 10000 ft. long, has been driven through the Ghats. The installation is likely to be ready in the early part of 1937.

According to present indications, the Madras Government will take in hand the Periyar River Hydro-electric Scheme after the completion of the Mettur Project. This is expected to yield about 15,000 kW which will be available for the power needs of the southern portions of the Presidency.

A start has been made with another Hydro-electric Scheme in the Bombay Presidency by a private company at Satara. The Urmodi River which drains into the Kas Tank is the ultimate source of the water, part of which is being used for drinking purposes. The portion of the water from the Kas tank required for the hydro-electric installation at Satara has been taken through a channel and pipes giving a vertical drop of 540 ft. and is developing 140 h. p. This is one of the smallest hydro-electric installations from the point of view of power developed. It may nevertheless prove a success with the co-operation of the city Fathers and industrialists.

A company was formed in July 1934 for putting up a large hydro-electric station to supply power for the production of aluminium in Kolhapur State.

These are the water-power schemes which are likely to materialise before 1940. Before mentioning the possibilities of the more distant future, it will be well to pause and take a bird's eye-view of the existing Hydro-electric Installations and draw a comparison between them.

Which is the First?

Special mention will now be made of particular installations which for some reason or other are noteworthy or outstanding amongst their peers that produce water-power in India.

The Tata Power Co.'s Installation at Bhira (in the Konkan or coastal region south of Bombay) is the largest in the matter of output of power, the mechanical horse-power being 135,000 h. p. and the electrical kilowatts 87,500 in a single station. This is more than the combined h. p. of any two of the other hydro-electric plants in India. The Mulshi-Bhira plant is also first in point of size of penstock, which is 7 feet in diameter for three of the pipes. The tunnel for the Reservoir of this Plant is likewise the longest, being 14,850 feet, as well as the largest in sectional area, this being 140 sq. ft.; the next is that of the Uhl River Scheme, 14,202 ft. long and 67 sq. ft. in area.

Among dams for water-power plants, the Krishna Raja Sagar Dam is the longest, being 8,600 ft. long; the Shirawta Dam, one of

the three main dams of the Tata Hydro Co. is the next longest, being 7,606 ft. long, inclusive of the waste-weir: the pipe-line of this company's installation is no less than 12,500 ft. from the Forebay to the Power House at Khopoli; the Pykara pipe-line is 11,270 ft. long. The Thokarwadi Dam of the Andhra Valley Co. is 190 feet high and the Lake 9 miles long. Comparable with these dams are the Bhatghar and Mettur Dams, the former 190 ft. high and about a mile long and the latter 176 ft. high, 170 ft. wide at deepest foundation and 5,300 ft. long; but the Mettur Lake will be the largest in India, 93,500 million cubic feet in capacity. The last two Dams are however for irrigation *cum* power schemes, like the Krishna Raja Sagara which is 130 ft. high. The biggest lake for a purely water-power scheme is that of the Tata Power Co. at Mulshi, being 16,120 million cubic feet in capacity. The capacities of Krishna Raja Sagara and Bhatghar Lake are 43,934 and 24,198 million cu. ft. respectively.

The supply channel for the Jhelum Power Installation is the longest, being 6½ miles long; the next being the duct-line of the Tata Hydro Co. 22,580 ft. long. The supply channel of the Cauvery Power Scheme is able to carry the very large flow of 1,200 cusecs and is 17,920 ft. long.

The highest 'head' is that of the Pykara River Project, being 3,080 feet, the next being that of the Uhl River Scheme, viz. 1,800 feet. The highest natural waterfall is that of Gersoppa, 830 feet. The maximum spacing for the Uhl River Scheme towers being 3,600 ft., this power system is from the point of view of span of H. T. lines *facile princeps.* For Pykara lines, the maximum span is 2,670 ft. and the normal 1,050 ft.–the corresponding figures for the Tata lines are 1,185 and 500 feet.

The Upper Ganges Canal has a very large flow at Bahadrabad, the minimum cold weather discharge being no less than 4,000 cusecs, which is more than that of any canal or supply channel furnishing water for a hydro-electric installation. There are 13 falls on this Canal, from Ranipur at 5 miles to Sumera at 163 miles, the cold weather minimum flow varying from 4,000 to 1,162 cusecs. The Ganges Canal Power Scheme is remarkable for the reason that several low-fall plants at different points will generate electricity which linked into a Grid will supply a large network over a widely-scattered area in the United Provinces. The Govt. have financed the Scheme; but the sale of energy will be through certain commercial undertakings, of a private character, guaranteeing a fixed revenue to

Government. At certain places, power will be used to raise water from lower levels to supplement other sources or to fill up depleted reservoirs or canals.

The Uhl River Scheme is the first from the point of view of the pressure or voltage employed and distance covered for transmission purposes; the voltage being 132,000 volts and the distance for this voltage 213 miles. At terminal stations, the pressure will be reduced to somewhat lesser voltages and power will be transmitted to longer distances still. This scheme is also worthy of note for the reason that it has been so designed that overhauling and repairs of high tension apparatus can be carried out with safety and without interruption of the supply. The Punjab Govt. have moreover undertaken to supply energy from the Mandi plant themselves direct to urban consumers, this being the first instance of a Government doing so.

Recent Hydro-electric enterprises on a large scale have been undertaken by Governments who alone can advance, in the present circumstances, the capital required for the expensive initial stages for schemes that do not bring in quick returns and would consequently daunt ordinary business concerns. Future generations of Indians will reap the benefits of these big undertakings and bless the engineers who overcame physical and financial obstacles. The costs of Indian hydro-electric schemes can be known by turning to Appendix III of this Book.

Probable Future Projects.

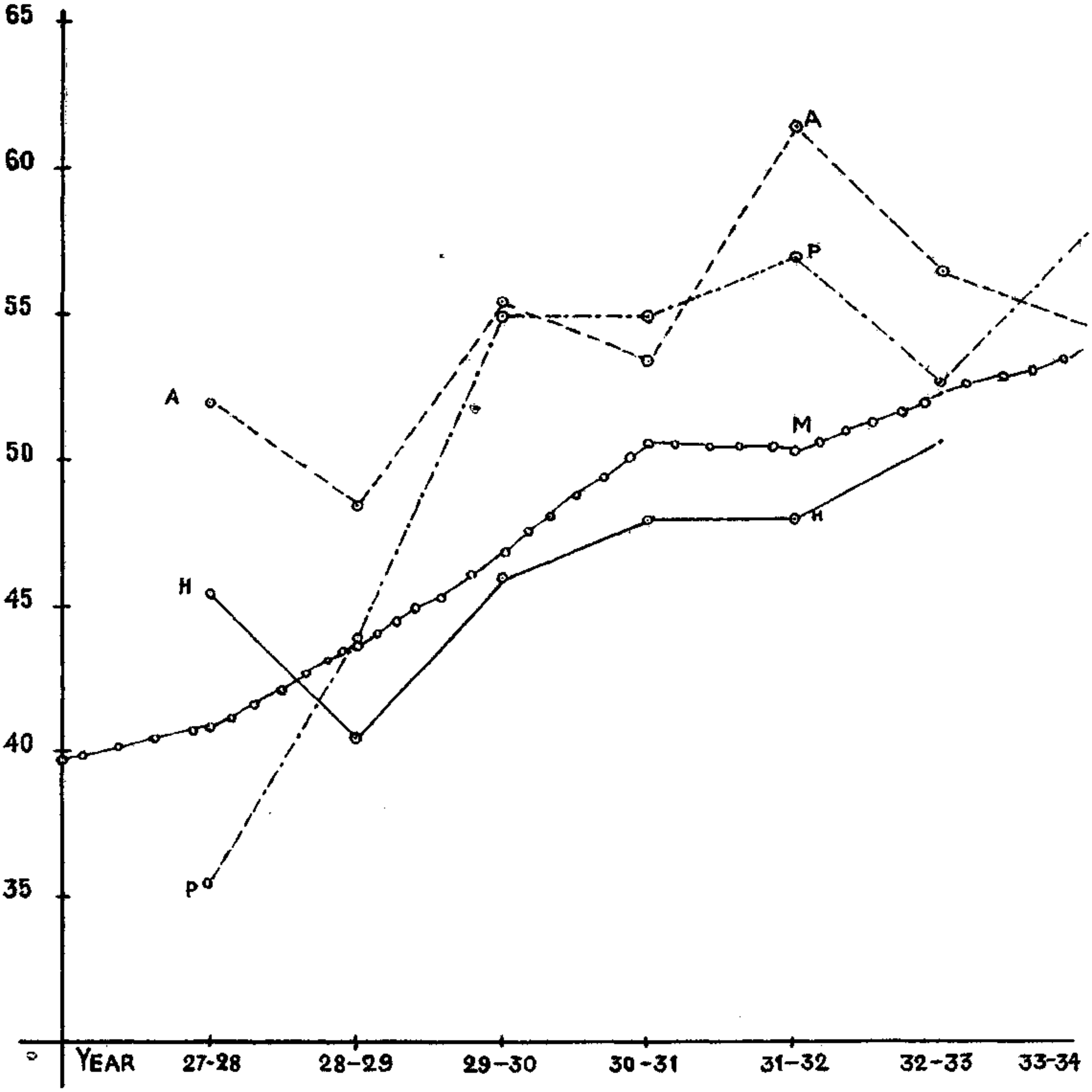
As regards the water-power projects likely to be taken in hand at some future date, reference is invited to H. E. I. L, page 243. As a general rule, hydro-electric development is unlikely in States or provinces blessed with natural supplies of coal or oil, or where these fuels can be had cheap i. e. at prices which enable power to be produced at rates low enough to preclude the possibility of hydro-electric power competing with them in the trade market with any hope of success. For instance, Assam and Bengal remain quiescent in the matter of harnessing their hydraulic resources for power purposes, in spite of natural facilities in the shape of the remarkable rainfall at Cherrapunji and the large Teesta river, both widely recognised as potential sources, because of their high altitudes, of a plentiful supply of power. The same applies to coal-containing provinces or provinces adjoining those containing coal or receiving oil at low rates, e. g. Bihar and Orissa, Central Provinces, Sind, Central India and Hyderabad (Deccan) particularly when facilities for water-power development are

not so pronounced as in the Bombay and Madras Ghats. Although in seaports like Bombay and Madras, oil could be had at low rates, abundant water facilities not too far from them make it possible for hydro electric concerns to flourish and to inspire confidence leading to further development of the same nature on a larger scale as the years roll by. Provinces not blessed with seaports and with coal mines are pre-eminently suited for hydro-electric development, if the quantity and fall of water are ample and a good demand for power is present or can be created. Mysore, Kashmir, United Provinces and the Punjab fall under this category. We have seen above that water-ower plants have been put up in all these States and provinces. In Bombay, the Tata hydro-electric schemes have followed, one on the heels of the other, for the simple reason that there is a scarcity of coal and a plentiful supply of rainfall-water stored on the tops of the Ghats. Their success is clearly seen in the attached graph for Revenues (Fig. 3). In Poona, good coal sells at about Rs. 20 per ton. The same price holds at Lahore in the Punjab, where the big Mandi Scheme has just been completed, a scheme which provides 36,000 kW at present, but will give 72,000 kW after the second stage, 120,000 kW after the third stage and 150,000 kW ultimately. Similarly, Pykara provides at present 30,000 kW, but provision has been made for considerable extensions. Ultimately, this project could furnish 100,000 h. p. It is *the precursor of other Hydro-electric schemes to be taken up one after* another in the Madras Presidency, at places where the Ghats offer excellent natural facilities for water-power development.

The maximum amounts of power possible from sites in the Madras Presidency are believed to be as follows:—Kolab andMachkand in Viziagapatam District 70,000 h. p. each, Periyar 55,000 h. p., Mettur 45,000 h. p., Papanasam 40,000 h. p., Cholatipuzha 40,000 h p., Silent Valley and Kumbar 30,000 h. p. each, Pinjakave 20,000, Thalipuzha 10,000 and Godaveri canal falls 10,000 h. p. The Kundah River scheme (H. E. I. I. pp. 169 and 170) has been indefinitely shelved (the Chief Engineer informs me).

At ten of the Falls of the Upper Ganges Canal, of which only four have been developed so far, 47,000 h. p. is available and waiting to be harnessed into the service of mankind. This has however to be supplemented by oil-engine reserves for use when the water in the canal is insufficient, as happens every year or so on the system.

Water-power will probably be generated in connection with the Tungabhadra River Project, as in one section of the main canal on the Mysore State side there is a good fall in water-level.



H—HYDRO———, A—ANDHRA - - - - -, P—POWER -·-·-·-, M—MYSORE -o-o-o.

Fig. 3. REVENUES IN LAKHS OF RUPEES OF TATA WATER-POWER COMPANIES AND OF MYSORE GOVT. ELECTRICAL DEPARTMENT

(TO FACE PAGE 20)

The Cauvery Power Scheme has gone on from strength to strength; and besides Sivasamudram, Kannambadi, where the Krishna Raja Sagara Dam is situated, is equipped to provide power from water. Mysore State is also likely to develop the world-famous Gersoppa or Jog Falls in the not-distant future. The progress of certain Indian Electricity undertakings can be seen from figures of revenues given in Appendix VI.

Success has not crowned to the same extent the ambitious schemes of Jammu and Kashmir State, which were capable of being developed to generate over 20,000 h. p. and of being so extended that not only could electric railways be run there and electro-chemical industries started but power could also be supplied from Peshawar to Jammu in Northern Punjab (see H. E. I. I. pages 60 and 246). Similarly, the magnificent Koyna River scheme of the Konkan Ghats of Bombay, which would have provided power sufficient for the needs of the Southern Mahratta Country, including the electrification of portions of the M. & S. M. Railway, has not yet materialised in spite of the great potentialities of the project (*vide* H. E. I. I. page 94).

The Sankheda Taluka Hydro-electric Project of Baroda State which was to store and utilise the waters of 3 rivers, the Orsang, Heran and Unch to develop 4,000 kW has not been taken in hand, as it was feared that the Scheme would not be a financial success, though a good market for power exists at Baroda, 24 miles from the site of the works. I am indebted to the State Engineer for this information. The Khodiar waterfall (Amreli Dist.) is likely to be harnessed.

In the Rewa State of Central India, there are 3 falls, one of about 146 ft. on the Tons River which is called Purwa, one of about 300 ft. on Ghoghar Chachai and one on Mahanadi Keoti. By making arrangements to utilise the fall of level in the rapids above and below the Purwa Fall, a head of about 400 ft. could be created and over 30,000 h. p. developed. Bombay firms who surveyed the falls found the scheme too expensive: the State Engineer has kindly sent me this information.

No hydro-electric installation exists as yet in the premier State of Hyderabad (Deccan): though in 1931 a big hydro-electric project was reported to be in contemplation. The State possesses a plentiful supply of coal and this fact perhaps accounts for its delay in developing its water-power resources. Proposals for hydro-electric installations in Gwalior State had to be abandoned, the Chief Engineer informs me, as the schemes would have been financially impossible.

In 1933, a report appeared in the Press that the possibilities of the Dudh Sagar and other waterfalls in Portuguese territory near Goa were under investigation. I understand that the Marmugao Harbour Electric Scheme has already been taken in hand. It is reported that the Pench River scheme for supply of power to Nagpur mills and for G. I. P. Ry. electrification from Igatpuri to Bhusaval is under consideration (H. E. I. I, p. 170).

The harnessing of the Nerbudda Falls at a suitable spot in the Bombay Presidency (somewhere near Surpans) has been proposed (H. E. I. I. p. 233).

Indian Power Resources.

(Electrotechnics, Apr. 1935—T. D. Chatterjee)

Water-Power		Coal			
Probable Ordinary Minimum Power (kW)	Probable Maximum for Development (kW)	Actual resources in Tons	Output of Indian Coal fields (Tons) 1916	1917	1918*
7 512 000	12 680 000	445 833 000	17 254 307	18 212 916	20 721 543

* Taking 1 h p-year as being equal to 4 tons, the 1918 output is capable of yielding 5 180 385 h p-year or 3 863 960 kw-yr, which is only ½ of probable ordy. min. available water power, out of which hardly 5 per cent. has been developed or is in course of development.

CHAPTER III

WATER-POWER ACHIEVEMENTS AND TENDENCIES ABROAD.

Having outlined the achievements of India in the field of hydro-electric endeavour, let us turn for a while for inspiration to other nations that have forged ahead of ours in this field, particularly those of North America who have led the way and allured the older nations of Europe, whence they migrated, to emulate their examples and attempt to attain the heights reached by them. Considering the large leeway that India has to make up in this matter compared even with European countries, it will be long before the level of progress of Western people is reached here, but we can not fail to be stirred by their achievements and to be led to make determined efforts to approach, if not attain, the high-water mark of industrial advancement set by them to serve as a standard for others following in their wake. While marching forward towards the goal, we should avoid the pitfalls that had beset the paths of others and profit by the lessons their experience teaches us. If this were done, our being late in the field will not be a disadvantage to us in the long run. For this purpose, a careful study of their trials, adventures and efforts–their attempts, failures and successes—is necessary. Space does not permit of an exhaustive account of the nature just indicated being given in this small volume but brief mention will be made of a few outstanding examples of progress and of present-day tendencies in water-power practice abroad, where great strides have been made and vast areas are served by electric power transmission systems emanating from large and small hydro-electric central stations which are often situated far from the centre of industrial activity but in some cases bring about the creation of industrial cities close to themselves in erstwhile solitary places.

All the existing Indian hydro-electric installations of India taken together have a capacity of about half a million electrical horse-power. A single province of the British Dominion of Canada has developed three times this amount of power from water. In December 1933, the load supplied by the Ontario Co. was 1,440, 046 h. p. In the province of Ontario, nearly 40 water-power plants are at present in working order. Two hundred to three hundred million pounds

sterling have been invested in central electric power stations of Canada and latterly development has proceeded at the rate of 100,000 h. p. per year. The total hydro-electric power of the Dominion is 670 h. p. per 1000 of the population. '*Distribution*' for January 1933 gives the following details about the system of the Hydro-electric Commission of Ontario which supplies power to about 757 municipalities:—

TABLE 2

Main transmission lines	5,000 miles
including 220,000 -volt lines	400 „
132,000 „ „	190 „
110,000 „ „	1,100 „
Lines serving rural power districts	8,200 „

In India, we have no power transmission system approaching this; there is not a single system where a pressure of 220 kilovolts is used; there is not one system of H. T. transmission covering 1,100 miles which is under one controlling authority. The only 132,000-volt system is that of the Uhl River Project. Table 53 of H. E. I. I. gives the principal transmission data of American high-voltage stations.

The second British example, that should serve as a beacon to lighten the path of Indian industrialists who are desirous of going forward with schemes for providing and employing electric power wherever possible and feasible, is that of the Electricity Grid of Great Britain, which has cost 27 million pounds sterling and given employment, directly or indirectly, to 200,000 workers. Other facts and figures about this Grid are as follows:—

TABLE 3

26,265 pylons; 170,000 tons of steel; 12,000 tons of aluminium; 500,000 tons of cement; 200,000 insulators; lines (H. T. pressures) 4000 miles; 132,000 -volt lines, 2894 miles; 70 p.c. loaded in 1935 and fully in 1940; 25,000 million units; the first 75,000 kVA transformer.

It must however be noted that the British Grid is not dependent upon water-power installations.

A measure of the progress made in the United States of America is provided by the following bit of information culled from *Electrical Engineering* (*May 1934*):—The first hydro-electric central station was constructed in 1882 at Appleton, Wisconsin,—a 250-light

installation. The aggregate installed capacity of hydro-electric plants in the United States now is more than 15 million horse-power. Reference is invited to Table 50 of H. E. I. I.

As compared with this, the aggregate installed capacity of Indian hydro-electric plants is less than ½ million h. p.; the total installed generating capacity of all kinds of electrical undertakings in India is less than one million horse-power.

There are about 50 hydro-electric stations with full load of more than 10,000 kVA each in the small country of Switzerland, some of them having a capacity of 66,000 kVA or more. In Switzerland, the total number of water-power plants is over 300 and electricity is used for railways and for heating on a large scale, see H. E. I. I. page 260. Automatic stations have not become common in Europe, but in America there are several water-power stations which automatically shut down on the hydraulic as well as electrical sides whenever there occurs a disturbance and inform the man in charge by telephone. For intentionally starting or stopping the sets, a man must operate the necessary gear. If the sets work according to a time-table, the man can start the sets, go away for some other necessary work and return at the time when the station is to be shut down

In the paragraphs of this chapter which follow, extracts will be given from the Survey of Hydro-Electric developments printed in the June and July 1934 numbers of *Electrical Engineering*, the Journal of the American Institute of Electrical Engineers, which surveys not only the water-power of the United States of America but also to some extent that of the world and is therefore worthy of our serious consideration. Remarks within brackets are by the present author, and are made with a view to make the subject-matter more interesting to those concerned with Indian Water Power Plants.

" The Boulder Dam plant, now under consideration on the Colorado River, is the most outstanding example of a plant on a river having extreme flow fluctuations that will be regulated artificially for irrigation and power purposes; these fluctuations will be regulated to an extent (that was) never previously attempted and that probably will not be repeated for many years on such a scale. (The Cauvery Falls Scheme of Mysore State is a case in point, see page 135 of *Hydro-electric Installations of India* for facts and figures of minimum and maximum discharge, with and without storage). The 12 Boulder Dam generators are greater in capacity and physical dimensions than any previously constructed;– 82,500 kVA, 1,000 tons in weight, 40 ft. over-all diameter and 32 ft. height above floor level. The lake is the

largest artificial lake in the world". "In many cases the cost of the desirable amount of storage is prohibitive and best economy is obtained by partial regulation of the water flow and complementary adjustment of the energy demand. (This applies to several Indian water-power projects. The Pallivassal scheme of Travancore State described in Chapter XVII provides for developing the total output without any storage of water).

"The financing of most of the water-power developments in outlying poorly populated districts was made possible only by the demand for electrical energy that was created by electro-chemical industries. This not only turned the wasted water energy to useful purposes but incidently resulted in these districts becoming modern highly developed communities. The latest developments at the upper part of the Saguenay River in Canada are quite representative in that respect. The Saguenay flows from the Lake St. John which acts as a natural regulator of the water flow of the river......The plants already built or proposed on that river are to supply large blocks of power to electro-metallurgical and paper industries......The Dnieperstroy development on the Dnieper river in Russia is a sample of such a development built on a very flashy river with a limited amount of artificial regulation. The economic justification of this development is based upon the expectation that the power demand of the industries yet to come can be regulated to the necessary extent. (The Jhelum Power Installation of Kashmir State is an instance of this in India, vide page 24 of *Hydro-electric Installations of India.* Considerable amount of money was spent on the investigation of a scheme to supply power for the manufacture of cyanamide and fertilisers near Jubbulpur in the Central Provinces, vide page 233 of the book just mentioned).

"The recent considerable increase of developed water-power of Norway follows along the same line. The utilization of the vast available but undeveloped water-powers of the Asian mainland, of Africa and of South America in all probability will be made possible by the same gradual process of establishing industries demanding large blocks of cheap electrical energy. ("For example, the Himalayas are provided by nature with an abundance of waterfalls capable, when harnessed, of generating vast supplies of electricity. It is probable that before 2029 an intensive industrial life will grow up among the foothills of this mighty range, drawing its life-blood from great power stations high in the gorges and ravines of the mountains," so wrote Lord Birkenhead, once Secretary of State for India).

"All developments of appreciable size put into operation during the last decade were alternating-current developments even in cases where the bulk of the generated electric energy had to be changed into direct current for ultimate use in electro-chemical or electro-metallurgical industries. The Lochaber direct-current development of the British Aluminium Company is the only exception. (The only continuous current generating plant associated with a hydraulic power development in India will be that of the Kolhapur State. vide chapter VIII. This plant is also to be for the production of aluminium. Electro-chemical industries depend upon large quantities of current for electrolysis or for heating or for both).

" Interconnections provide economical and operating benefits that sometimes make it possible to break through territorial boundaries. The interconnections between the power systems of Switzerland and those of France, Germany, Austria and Italy are the most outstanding instances of an international widespread interconnected energy supply system. (Mysore State provided electricity required by Madras Government for the construction of Mettur Dam, and in future the plants of these administrations and of others in South India may be interconnected when the areas covered by power lines extend and industries multiply).

"The combination of many water-power developments of different kind and character often located on different drainage basins, some with storage capacity and some without, may result in a satisfactorily regulated system even without including any thermal plants in the system. The developments that are combined by the Hydro-electric Power Commission of Ontario may be cited as an example. Here the backbone is formed by the Niagara Falls developments." (The Tata trinity is an outstanding example of this sort of development in India. The Tata plants are on different drainage basins and the lakes for the three hydraulic works are far apart; but the generating stations, which are also at great distances from one another, are interconnected. The Upper Ganges Canal installations, of which four have been so far put up, are located at different points of the same canal and will also wherever feasible be interconnected. Being situated on the Canal of the mighty Ganges, no extra storage reservoirs are specially provided for these installations. Descriptions of the above-mentioned installations will be found in Chapter XI; the Tata plants are described both in this book and the earlier one on Hydro-electric Installations of India).

"During later years hydro-electric developments are gaining in importance in such localities as, for example, the eastern part of the

United States where very large loads are carried by thermal plants. The comparatively small increment cost of additional capacity of hydro-electric plants makes it advantageous to provide equipment many times in excess of the average load. If such plants are operated only a limited number of hours, comparatively large peak loads can be handled. The recent Susquehanna River developments at Conowingo (Md.) and Safe Harbour (Pa.) are typical not only in that respect, but also as developments that could not be justified economically without a previously developed large thermal capacity. (This has been true to some extent of the Pykara development in South India and of the Uhl River scheme of North India; in both cases thermal stations existed or were put up to be largely relieved of their loads later by power from hydro-electric plants; in some instances the steam or oil plants were entirely done away with or shifted to other cities. After the Poona Supply Co. was connected to the Tata system, its thermal plant was transferred to Nasik Road to supply electricity to Nasik and Deolali).

"A steam unit under stand-by conditions may pick up the load quickly but ordinarily requires a long time if both boilers and unit are cold. Consequently the hydro-electric plant is better adapted for stand-by service or as a spare unit. Very often the stand-by characteristics are improved by having the unit permanently connected to the system, idling the turbine and utilizing the generator as a synchronous condenser, to improve the electrical characteristics of the system. The energy consumption of such idling units is reduced sometimes by automatically breaking the vacuum or by forcing the water from the turbine runner by means of compressed air. If a failure occurs in some part of the system, such an idling unit may be loaded to full capacity within a few seconds. (This is a good suggestion for the Mohora plant of Kashmir and the Naini Tal plant of the United Provinces, where there exist spare sets, of which the generators could be used as synchronous condensers, if the design permits, to improve the power factor and reduce the loss, till such time as arrangements are made to utilise the installations to their full capacity by extending the system or starting industries).

"At present the use of pumped storage plants operating on a complete pumping cycle is rapidly gaining in importance due to the wide use of interconnections. In spite of the fact that under average conditions the efficiency of a complete pumping cycle is only about 60 p. c. it may be economical to invest 100 kWhr at times of low demand to secure a return of 60 kWhr when energy is badly needed. Most of the pumped storage plants are located in Europe. One of the

largest pumping storage plants located at Niederwar near Dresden in Germany is built to meet the peak load requirements of a purely thermal system. In spite of the small storage capacity of the Safe Harbor plant it is proposed to take care of the anticipated increase of the peak load of the system to which that plant supplies power by introducing a pumping cycle at Safe Harbor, using steam power for pumping instead of increasing the steam generating capacity. (In connection with the Ganges Canal Power system, considerable quantities of water will be pumped from other streams by electric pumps worked by power from the hydro-electric stations or their thermal assistants, the water so pumped being however mainly utilised for irrigation, not for storage for power purposes. Reference to Chapter XI should be made for particulars. Utilisation of 'dead water' of a plant by pumps to replenish the supply in the forebay is referred to on page 108 of H. E. I. I. "In the Sillre power station of Sweden, during periods of light load on the network, the surplus power is fed to the generating unit which acts as a motor and drives a pump to refill the storage basin of the station". *Asea Journal,* March 1934. Mr. F. J. Taylor's article on 'Pumped Storage' in *Electrical Review* for Sept. 7, 1934 may also be read).

"Both Pelton and Francis turbines sometimes are installed in plants having sufficiently high heads. Then the Francis turbines carry the base load at favourable efficiency conditions and the Pelton turbines having the better efficiency at part loadings carry the fluctuating loads. For medium-head plants Francis turbines of different characteristics are used, again adding to the overall efficiency of the plant. Introduction of the (Caplan or) Kaplan turbine with its very flat efficiency curve under different load and head conditions puts low-head developments in a favourable position so far as average efficiency is concerned. Since Kaplan (or propeller) turbines may be overloaded considerably without an undue reduction of efficiency, it is possible in large installations to reduce the cost by the elimination of spare units. The 54,000-h. p. Alexander development on the Nipigon River in Canada represents the largest automatic plant put into operation to date. (At the Sivasamudram station of Mysore, Pelton turbines were originally put up but they have been replaced gradually by Francis or reaction turbines,-draft tubes are utilised to add to the effective head and thus increase the power generated. At the low-fall installations of the Ganges Canal, Kaplan turbines have been put up. The interested reader will find notes about these turbines along with diagramatic sketches of each in Major Jhonstone Taylor's articles in *Indian and Eastern Engineer* for July and August 1926,

where other hydraulic appliances are also described e. g. Lawaczeck turbines, the Banki turbines, the hydrocone and the Mody spreading tube. Lea's Hydraulics may be consulted if desired).

N. B.—The world's second highest dam, at Corps, Isere Dept. France, has a power station at a lower level working under a direct head of 328 ft.,—dam height 390 ft. This will be eclipsed by the Boulder Dam of U. S. A., 727 ft. high, costing £ 24,000,000.

" High head developments would be those using impulse turbines, better known the world over as Pelton turbines; medium head developments, those using Francis turbines; and low head developments, those using any kind of propeller turbines with fixed or adjustable blades including the well-known Kaplan turbines......... In Europe, 76 p. c. of the low head turbines and nearly 13 p. c. of all turbines produced are of the Kaplan type. The probability is that the future trend in the United States and Canada will be to increase considerably the percentage to the aggregate horsepower capacity of Kaplan turbines.............

" According to the best possible estimates, the developed waterpower of the world in the year 1933 approached 60 million shaft horsepower for turbines installed and in actual operation....About 24 million horsepower or 40 per cent. of the world total is located on the North American continent, about 28 million or 47 per cent. in Europe and about 6 million or 10 per cent. in Japan. The appreciable waterpower possibilities are not utilized at all in the less developed countries, most of which are situated in the mainland of Asia, Africa and South America.............

" The present tendency is to concentrate in a single development as large capacities as possible......a few of the power plants in the United States and Canada after ultimate development will be in the 2,000,000-h.p. class. Only a few years ago, such large plants were considered impracticable. The expectations are that the future developments on the Columbia River in the United States and in some parts of Africa and South America will result in power plants of considerably larger capacities. (There are about 50 major developments, viz. of an ultimate capacity of 200,000 h.p. or over in the world :—Grand Coulee, U. S. A. Columbia River, leading with 2,660,000 horsepower. About 300 plants are in operation or under construction in North America, the ultimate capacity of which is more than 20,000 horsepower.)

TABLE 4

Developed Water Powers of the World, in millions of horsepower at the Turbine hSafts.

United States	15.8	*India*	0.7
Canada	7.0	Mexico	0.6
Italy	7.0	Finland	0.5
Japan	5.6	England	0.4
France	4.0	New Zealand	0.3
Germany	3.5	Jugoslavia	0.2
Switzerland	3.5	Czechoslovakia	0.2
Norway	2.5	Chile	0.2
Sweden	2.0	Ireland	0.2
Spain	1.2	New Foundland	0.2
U. S. S. R.	1.0	Chosen	0.1
Austria	1.0	Tasmania	0.1
Brazil	0.8		
		Total	58.6

The output of electrical energy — whether produced by water, the white fuel, or by other fuels — per head of population is given for 1930 by the following figures in Kilowatt-hours (*Times of India*, Aug. 24, 1934) :—

TABLE 5

Electrical Energy in kW-hr per head of population.

Norway	3300	Austria	450
Canada	1900	England	370
Switzerland	1350	France	350
U. S. A.	1050	Finland	300
Sweden	825	Italy	270
Belgium	570	U. S. S. R.	60
Germany	500	*India	21

* The figure for India is based on my own calculation.—S. N.

CHAPTER IV.

PROGRESSIVE INSTALLATIONS OF MYSORE STATE.

The State of Mysore was the pioneer in the field of hydro-electric power supply for industrial purposes in India (see chapter IX of H. E. I. I. for details) and the well-known generating station at Sivasamudram, for which the nearest railway station is Maddur, has been altered and extended from time to time to such an extent that its external and internal appearance after the completion of the Eighth installation is absolutely different from what it was when first constructed in the beginning of the present century i. e. in 1902, when the capacity of the plant was 7,500 b.h.p., 6,000 e.h.p. or 4,500 kilowatts. The *second* installation was carried out in 1904, the aggregate horse-power then being 13, 750 b. h. p. or 11,000 e. h. p., 7,750 kW; the *third* installation in 1907 brought up the plant capacity to 16,450 b. h. p., 13,000 e. h. p., or 9,750 kW.; the *fourth* installation of 1914 increased it to 21,850 b. h. p. or 17,000 e. h. p. or 12,750 kW,—the channel being raised by 3 ft. to increase the supply of water; the *fifth* of 1918 provided for further increase of power to 21,000 e. h p. by the erection of a 5,600 b. h. p. or 4,000 e. h. p. turbine of the reaction type; the *sixth* installation of 1922-24 raised the capacity to 47,300 b. h. p., 34,000 e. h. p., or 25,500 kW. and involved the construction of a large transformer station and the replacement of the old impulse turbines. The *seventh* installation of 1928 further increased the power to 65,300 b.h.p., 50,000 e. h. p., or 37,500 kW and also raised the ½ mile-long low-crest diverting dam across the Cauvery River and the adjoining buttress, besides providing for the construction of a new silt reservoir, of an additional trolley track (one for passengers, another for material) and last but not least, the erection of two units of 9,000 b h.p. each. The *eighth* installation (1933) has raised the installed plant capacity to 56,000 e. h. p. or 42000 kW by replacing a set of 1500 kW by one 6000 kW set. There are now installed at Sivasamudram Power Station the following:—Two 1500 kW sets, three 6000 kW sets and seven 3000 kW sets. The capacity of the supply channel, which is 17,920 ft. long, is 1200 cusecs. The smallest sets are Escher Wyss Impulse wheels. Seven turbines are Boving turbines each coupled to a General Electric Alternator, 6 pole, revolving field, 3,530 Kilovolt ampere (3,000 kilowatt), 500 r. p. m., 2200 volts, 25 cycle; and three are 9000

h. p. turbines, reaction type, running at 375 revolutions per minute, each coupled to a generator of 6,000 kilowatts. The largest alternators are 2200 V, 7060 KVA, 6,000 kW., 375 r. p. m. three-phase, power factor 0.85; field current, ampere 255 D. C., from an Exciter coupled to a motor or to its own water wheel working at a head of 415 feet. There were 13 pipes, one for each Generator Turbine, the thirteenth being common for all the Exciter wheels. A new penstock, 63" in diameter, now takes the place of the pipe-line of the third installation. One of the turbo-alternator sets serves as a standby. The penstock-valves are designed to shut automatically if the water goes faster than at a predetermined velocity. They can be closed at will from the power house, whenever required, through remote-control apparatus. On the Bluff near the Forebay at Sivasamudram, there was a small Transformer Station for supplying power to the Mysore line only. The equipment of this station has been removed. Formerly, silt brought along with the river-water used to be taken out at the Forebay; now this is done in the "Forbes" Reservoir which is named after the late Chief Electrical Engineer and which is at a distance of about 1¼ mile above the Forebay; here the silt settles down and the clear water at the top flows back to the Supply Channel. At the base of the Bluff, there are three stations adjacent to each other but at different levels:—for the generating units and switchgear, for the step-up transformers and for the lightning arresters respectively. The generating station has a 45-ton travelling crane over it. There are draft tubes, connected to the tailraces of the turbines, whereby the gross head is improved by 12·5 feet. Two exhaust fans are run to keep the atmosphere inside the station cool. Besides the separate pipe for supplying water to the Exciter-Wheels, arrangement for an auxiliary feed from No. 2 Turbine-pipe has been made for use in emergency, to avoid breakdown or interruption of D. C. supply to the revolving fields of the alternators. The "head" is 122 meters, and the pressure of water 175 pounds per square inch, at the turbine-valves. Two exciters are driven by water wheels and two by 375-H. P. Induction motors, the former for use when no alternator is running.

In the Transformer Station, there are 5 banks of Transformers, one bank consisting of 3 transformers. Three banks have transformers each 3300 kVA and 2 have transformers, 1750 kVA each. (In the old station for the line to Mysore, the transformers were 750 kVA each, in 4 banks. The 2 new banks have transformers, 3300 kVA each.) Four transmission lines go out 24 miles to the Kankanhalli Station at 75,000 volts; from here, two go to Kolar Gold Fields 67 miles farther at 75,000 volts and two go 34 miles to Bangalore, which is supplied

through auto-transformers at 35,000 volts; the voltage is to be raised to 57,300 volts after some time and to 75,000 volts eventually. One of the four lines is usually kept in reserve, the other three being in use ordinarily. The lines from Sivasamudram to Mysore City, 57 miles away, formerly supplied the power at 35000 volts, now raised to 75,000 volts. For the line to Mandya from Mysore, voltage is raised from 4600 to 35000 by oil-cooled transformers. For regulation of voltage, two Tirrill Regulators have been installed near the Benchboard, where there is also an automatic Multi-Recorder to give a continuous record for the entire system. The peak load goes upto 36,000 kW. In the Lightning Arrester Station, thyrite arresters (Appendix No. V) and oxide-film arresters (see accompanying illustrations and Booklet No. III) have been installed. At the Kolar Gold Fields Receiving station, a 5000 kVA synchronous condenser has been installed. A transmission line was run in 1928 to Mettur Dam, to supply power for constructional works in connection with the Irrigation Scheme undertaken at that place by the Madras Government. Power supplied for rural irrigation is charged at $1\frac{1}{2}$ anna per unit, for mills at $\frac{1}{2}$ anna and for small industries at $\frac{3}{4}$ anna only. Of the electric power used in Mysore State, about 87 p. c. is used for industries and 13 p. c. for domestic appliances and lights. It is interesting to note that the total receipts of the Electrical Department of Mysore State for the year 1932–33 amounted to Rs. 52.30 lakhs; the ratio of the working expenses to this was 20.86 per cent. for this year. The total capital outlay to date is Rs. 2,84,61,887, excluding cost of the Krishna Raja Sagara Works. Fig. 3 shows the rise in Revenue at a glance. Electric power service has been made available at Anekal, Begur, Attibele, Melkote, Chikballapur, Channapatna, Tumkur, Hassan, Arsikere, Devangere, etc. The total outlay on the electrification of small towns and on rural electrification amounted to Rs. 20,43,000 (*Journal of the Royal Society of Arts*, March 8, 1935). The total quantity of energy generated during the year 1932–33 was 178,000,000 units or kilowatt-hours. At the end of the year, there were 2,200 power installations and 19,312 lighting installations. More than 350 irrigation pumps and 10,776 street lights are now being worked electrically. 150 towns are scintillating with (25 cycle) electric lights.

B. Proposed Mysore Schemes.

New schemes of hydro-electric development in the Mysore State may be referred to in passing, to show that the State is not resting upon its oars in this matter. The river below Sivasamudram generating station falls about 200 ft. within 2 miles and can give about 20,000 kW at a power station to be located there (9th Installation). There

is one scheme for Mekadatu, another for Shimsha and a third scheme for harnessing the world-famous Gersoppa or Jog Falls having a natural drop of 830 feet, which would be less than what is technically termed gross " head ". These falls form the frontier boundary between British Karnatak and Mysore State. The Sharavati River, which falls here in four magnificent cascades, has a discharge of 80,000 cusecs. The " head " and "discharge" make the scheme attractive for hydro-electric development. The top of the Falls is about 1640 feet above sea level. Preliminary surveys have been carried out and gauging operations instituted and it is hoped that in the near future, steps may be taken to provide funds for the plant, equipment and works required for the purpose of putting up a power station at a suitable spot, not far from the base of the Falls. Visitors to this out-of-the-way but wonderful " Sight" will then be attracted in larger numbers than ever before, as the amenities of the region round about are sure to increase considerably shortly after electricity supply is made available, in its vicinity, for illumination and industrial purposes. Gersoppa power could easily be sent to the Bhadravati Iron works where it has been decided to manufacture steel in addition to pig-iron and paints. Forests and mines on the way could also use electric motors in preference to other contrivances. For the present, a line runs from Mysore to supply Sivasamudram power to the Bhadravati works, where a big demand exists. This line goes via Krishnarajasagar, Hole Narsipur, Hassan, Belur, Chikmagalur and is estimtaed to have cost Rs. 12.7 lakhs for a single circuit and Rs. 21.85 lakhs for a double-circuit line. The 8600 ft. long and 124 ft. high Krishnarajasagar Dam constructed 10 years ago across the Cauvery River at Kannambadi near the junction of the Cauvery, the Hemavathi and Lakshmantirtha rivers 60 miles from Sivasamudram may also be utilised to give hydro-electric energy upto 10000 H. P. at an estimated cost of 28 lakhs. This Dam cost 250 lakhs of rupees and stores about 44000 million cu. ft. of water. For facts and figures relating to this Dam across the Cauvery River and to the Headworks of the Cauvery Falls Hydro-electric Station, please see page 135 of '*Hydro-Electric Installations of India*' and for information pertaining to the Jog Falls Scheme reference may be made to pages 289 and 290 of the same book. The Mekadatu Rapids of the Cauvery River are 21 miles below Sivasamudram and 67 miles from Salem. The drop is estimated at 175 feet and the flow at 550 cusecs. The power that can be developed is about 8,500 e. h. p. Acknowledgments are hereby made to the Chief Electrical Engineer of Mysore State and to '*Electrotechnics*' for March 1934 for Dr. Ram Prasad's notes. The following extract from Garckes' '*Manual of Electrical Undertakings*,

1933-34' refers to the Mysore State Installation and System:- "*System*-Six 1750 kVA and nine 3333 kVA single-phase transformers transmit power at 70,000-78,000 V over 3-phase circuits to an intermediate station, Kankanhalli, 25 miles from the Power House; thence power for Bangalore is sent at 35000 V over duplicate 3-phase circuits 35 miles long and power for Kolar Gold Fields at 75000 V over duplicate line 67 miles long. Power for pumping station at Kolar Gold Fields is transmitted at 22000 V over a single line 10 miles long. The Bangalore pumping station is supplied at 35000 V over a single line 12 miles long while at Mysore the pumping station is supplied at 4400 V over a double line about 6 miles long. In Oct.

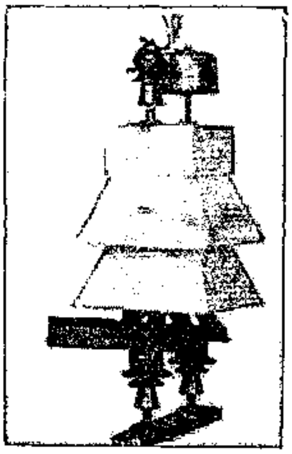


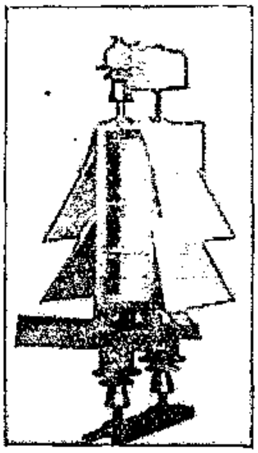
Fig. 4 Oxide Film Lighting Arrester (external view).

1928, a 60-mile duplicate line gave Mysore power, 3000 kVA, to Mettur Dam. Single-circuit transmission lines extended to several outlying areas at 35000 and 22000 V beyond Bangalore and Mysore cities for electrification of small towns and for supply of power to small irrigation pumping units in rural areas. In use at present,-440 circuit miles of 70 kV and 35 kV duplicate circuit main transmission lines and 600 miles of single circuit 35 kV and smaller voltage branch lines. For Local distribution, voltage is reduced to 2300 V at receiving stations. For lighting, frequency is changed to 60 cycles by synchronous motor-generator sets giving 2300 V which is again stepped down to 220 V for lamps. *Plant*. Six, 5600 BHP Escher Wyss Francis turbines each direct connected to 3000 kW GEC alternator; three 2750 BHP Escher Wyss impulse turbines, each connected to 1500 kVA alternator and two 9000 BHP Boving Francis turbines each connected to 6000 kW alternator. Exciter complement consists of two 250 kW 110 V exciters driven by Boving turbines and two 250 kW 110 V exciters driven by induction motors. Head.-423 feet between waterlevel at forebay and tailrace. For power purposes, 1200 cusecs allocated from the Krishnarajasagara reservoir and with this amount of water, with the type of turbine now installed, 50,000 H. P. *net* at L. T. can be generated.

During the year 1930-31, 169,491,060 units generated of which 112, 290, 200 supplied to Kolar; 36,084,600 to Bangalore; 14,601,480 to Mysore and 6,126, 700 to Mettur (Voltages in use at the)

Kolar Mines Station, 2300 V for ordinary purposes, 3300 V for hoisting. Single-phase 50 cycle 2200 volt transformed to 220/440 volts for 3-wire distribution. Steam plant used only in emergencies. Power purchased in bulk from Cauvery Hydro-electric Scheme."

Figures Nos. 4 and 5 accompanying this chapter, illustrate the external and internal appearance of an oxide-film Lightning Arrester, the description of which can be seen in the Author's Booklet No. III on '*Lightning Conductors, Protectors and Arresters.*' Figs. Nos. 6 and 7 showing the forebay and power station at Sivasamudram and Fig. 8 depicting the transmission system of the Cauvery Falls Installation may be seen in H. E. I. I. as Figs. 38, 41 and 39 respectively, which are three out of the seven photographic views of different parts of this installation to be found in '*Hydroelectric Installations of India,*' Chapter IX. Fig. 9 shows the trolley driven by a steel rope from a motor-driven winch for carrying passengers to and from the power station and the Bluff. Fig. No. 37 shows the Mysore State along with other parts of South India and makes clear the relative positions of the various water-power stations and electirc sub-stations. Figures regarding revenue and expenditure of the Mysore Cauvery Power Undertaking are quoted in Tables Nos. 6 and 7 which also give figures for the Tata-hydro-electric group, described in Chapter VI. The Lakkavalli Dam and Hydel Installation project is estimated to irrigate 900 sq. Kms. and deliver 9,000 h. p. The Mysore Govt. is expected to undertake the manufacture of electrical apparatus required for domestic use, having already started successful factories for making insulators, transformers etc.



Oxide Film Arrester
(Internal View Fig. 5).

TABLE NO. 6.

Statement of Gross Revenues of Tata and Mysore Hydro-Electric Schemes in Lakhs of Rupees.

Year	Tata Hydro	Tata Andhra	Tata Power	Mysore Govt. El. Dept. (gross)
1926–27				41.24
1927–28	45.43	52.30	35.35	41.29
1928–29	40.64	48.70	44.11	43.44
1929–30	45.80	55.44	55.14	47.45
1930–31	47.97	53.56	54.96	50.41
1931–32	48.06	62.31	57.01	50.33
1932–33	50.54	56.34	52.75	52.30
1933–34	37.97	54.77	57.64	36 (net)

The figures quoted above have also been shown in the form of a Graph, see Fig. No. 3. The net profit of the Tata Power Company for the year ended June 30, 1934 was Rs. 20 lakhs approximately and the net revenue of Mysore Electric Department Rs. 35·96 lakhs, 6½ lakhs being set apart for depreciation.

Other figures relating to the Mysore Electrical Undertaking and comparing it with other similar schemes are contained in the Report for 1932–33 by the Chief Electrical Engineer of the Mysore State from which the following few figures pertaining to power stations in India have been culled :—

TABLE NO. 7.

Revenues and Expenses of Hydro and Steam Undertakings.

Name of Undertaking	Gross Revenue in Rupees	Working Expenses in Rupees	Percentage of Wor. Exp. to Gross Rev.
Tata Hydro El. P. S. Co.	48,37,648	10,40,219	21·51
MysoreGovt. Cauvery Sch.	52,67,304	10,99,122	20·86
Madras El. P. S. Co.	£ 2,34,095	£ 1,11,980	47·84
Cawnpore El. S. Co.	£ 1,73,343	£ 58,548	33·79
Undertaking	Energy generated (Kilo-watt-hours)	Actual Expenditure (Rupees)	Cost per kilo-watt-hour (Pies)
Mysore, 1932–33	17,83,40,592	10,99,122	1·183

N. B.—The other latest available figures for Mysore have already been given above.

It should be noted that the Tata Hydro-Electric Power Supply Company and the Mysore State Electrical Department figures quoted above refer to Hydro-electric installations, whereas the Madras and Cawnpore Electric Supply Companies figures are for steam-electric undertakings. The reader can thus see for himself at a glance why the hydro-electric schemes of a large size score easily over even large steam-electric concerns. This explains why the Bombay Electric Supply and Tramways Company have scrapped their steam plant and following their example, other cities in the Bombay Presidency are doing likewise if the Tata Group agree to supply them with the electric energy they require.

TABLE No. 8

Rate of Growth of Cauvery Power Scheme.

Installation		Generating Sets			Type of Turbine	Aggregate		Flow in supply channel.
No.	Year	No.	E. H. P.	kW.		E. H. P.	kW.	
I	1902	6	1000	750	Impulse	6000	4500	250 cusecs
II	1904	11	1000	750	„	11000	8250	500 „
III	1907	11	1000	750	„			
		1	2000	1500	„	13000	9750	750 „
IV	1914	11	1000	750	„			
		3	2000	1500	„	17000	12750	900 „
V	1918	11	1000	750	„			
		3	2000	1500	„			
		1	4000	3000	Reaction	21000	15750	
VI	1922–24	3	2000	1500	Impulse			
		7	4000	3000	Reaction	34000	25500	1000 „
VII	1928	3	2000	1500	Impulse			
		7	4000	3000	Reaction			
		2	8000	6000	„	50000	37500	1200 „
VIII	1933	2	2000	1500	Impulse			
		7	4000	3000	Reaction			
		3	8000	6000	„	56000	42000	

N. B. The values for E. H. P. are approximately 4/3 of those for kilowatts.

Although the capacity of the plant installed is 42,000 kilowatts, it is not possible to develop more than 34,500 kilowatts (46,000 h. p.,) at present as the quantity of water permissible for power purposes is limited to 1200 cusecs. The peak load has reached the maximum at present possible and the Ninth Installation has therefore been taken in hand. This consists mainly of the conservation of water wasted over the waste weir of the Forebay during hours of light load and of the replacement of two 1500 kW. sets by one of 6000 kW. One bank of transformers of 5250 kVA. will be replaced by one of 10000 kVA. About a mile above the forebay, an 18-million-cu. ft. reservoir is being built. With this balancing reservoir, it will be possible to get 46000 kW. (61, 400 H. P.) with 1200 cusecs at the headworks, as the max. discharge between the reservoir and forebay could then be 1600 cusecs, based on 75 p. c. load factor. This Installation is expected to be finished by the end of 1937 at a cost of 13 lakhs.

The next site to be developed is likely to be 2 miles below Sivasamudram where a fall of about one third of the head at the present station could be harnessed to develop about 20,000 H. P. at another generating station-the two stations to be linked for the purpose of power supply like the Tata plants of Bombay. The electrification of the railway between Bangalore and Mysore was studied about 7 years but is not now under consideration. (The above is based on information kindly supplied by the Chief Electrical Engineer, Government of Mysore, Nov. 9, 1936). To improve the power factor, synchronous condensers had been installed at the Receiving Stations as follows:—3000 kVA at Oorgaum (Kolar), 1000 kVA at Bangalore, 1000 kVA at Mysore. More might be installed. The latest particulars regarding the principal Receiving stations are given in table No. 9.

TABLE NO. 9.

Particulars about Receiving Stations.

Place	Incoming Lines		Outgoing Lines Voltages	Kilowatts		Trans-formers kVA	Frequency Changers 25 to 60 cycles	Synchronous Condenser kVA
	Voltage	*Via*		Maximum	Normal			
Oorgaum Gold Fields	75000	Kankanhalli	22000* 2300	19000	14000	21000	...	5000
Bangalore	35000	,,	35000* 2300	7500	5700	12000	4	2500
Mysore	75000	direct	4600* 2300	5000	4000	10500	3 †	1000 †
Bhadravati	,,	Mysore	,, *	Iron and Steel Works			At Mysore transformers step up 4600 V to 35000 for Mandya.	
Mandya	35000	,,	,, *	Govt. Sugar Factory				

N. B.—Kankanhalli Switching Station receives power at 76000 V from Sivasamudram Station and passes it on at the same voltage to Orgaum, but

* The figures after which * occurs show the voltages at which power is sent to the Water Pumping Stations of the different places mentioned above.

† Power factor in Mysore is not low because there is not a large induction motor load and because the frequency changers consist of synchronous motors coupled to synchronous generators.

reduces it by Auto-transformers to 35000 V for the supply to Bangalore. Mysore Station like-wise passes on the power it receives for Bhadravati without reducing the voltage. The important roads and streets in Bangalore and Mysore are lit by series lamps supplied by Constant-Current transformers installed at the receiving stations; ordinary thoroughfares being lit at 25 cycles, 230 V, from the parallel system of supply. For house lighting, current is supplied at nearly 60 cycles per second from the frequency changers installed in the respective receiving stations, at Mysore and Bangalore. Except for the line to Mandya which has oil-cooled transformers, the high-tension transformers in the receiving stations are water-cooled as well as oil-cooled. Except at Mysore receiving station (locally called Forbes Transformer Station) where lightning arresters of the Oxide Film Pellet type are used, the large receiving stations have Thyrite Lightning Arresters.

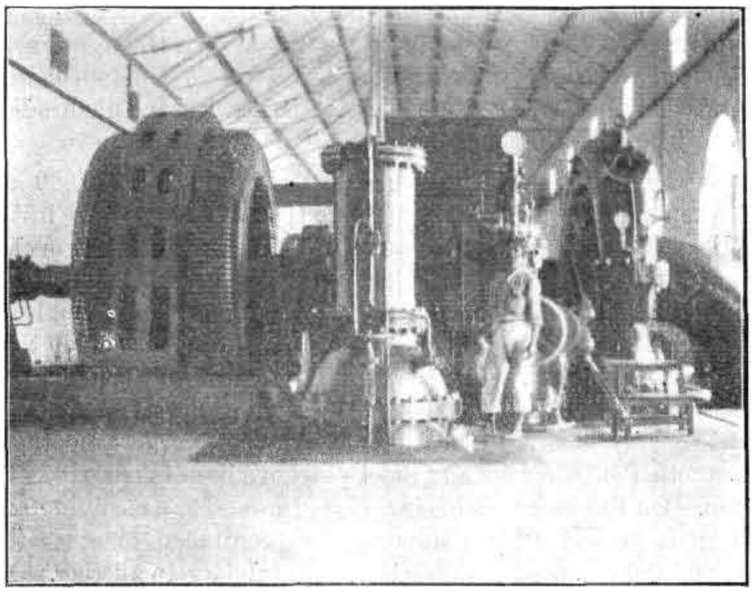


Fig. 7 a. Generating Units, (Boving and Co.)
SIVASAMUDRAM.

CHAPTER V

WATER POWER PLANTS OF JAMMU AND KASHMIR STATE.

Detailed descriptions with several illustrations have been given of the water-power installations of Jammu and Kashmir State in Chapters III and IV of 'Hydro-electric Installations of India'. Principal particulars and latest facts and figures relating to the generating, receiving and transforming stations are given below in a Table compiled from the Return for Sept. 1933, a copy of which was kindly supplied to the Author by the Chief Engineer, a colleague of the former when he was employed as an electrical engineer in the State on his return from the United States. A few points worthy of mention may however be stated at the outset, lest the picture be considered incomplete without them.

The Mohora plant could be extended to give upto 10,000 kW, if and when required, but at present, four 1000 kVA. sets are installed. Duplicate H. T. lines go out from it carrying current at 25 cycles per second and at 30,000 volts, which could be altered to 60,000 volts when the load increases considerably. At the stations supplying a large lighting load, the frequency is changed to about double the line frequency. Srinagar, being the capital, provides the principal load. Besides the receiving station, which is located at the silk factory where electric energy is used for heating purposes on a large scale, there are several other sub-stations and the lines have been taken out as far as Pattan. On the way to Srinagar, H. T. lines go to a receiving station at Baramula and from there they are continued to other towns, Doabgah and Sopur in one direction and Gulmarg in another.

In addition to the Mohora installation, Kashmir possesses another site on the Jhelum River for hydro-electric development. This is situated near Muzzarabad and is considered capable of giving 150,000 kW. 'The site is situated in the Sirmur series and Nummulitic geological beds, which are particularly suitable for various electro-chemical industries as well as for portland cement.' T. R. W. P. R. page 138. The Mohora installation has a head of 400 feet, that at Muzzafarabad or Kohala on the Murree–Kashmir road would have a working head of 750 feet.

Turning now to the Jammu Province of the State, the waterpower plant at Jammu works on the low head of about 26 feet, being located on a canal of the Chenab River, and even after alteration and addition

has an aggregate capacity of only 1072 kVA. The supply here is 3,000 volts at 50 cycles per second. A bigger installation on the Chenab River proper, not merely on one of its canals, is possible at Riasi in the Jammu territory, which would generate up to 29,000 kW. and have a head of 150 feet. (T. R. W. P. R. p. 137). In this connection, reference is invited to the remarks occurring at the bottom of page 59 and the top of page 60 of 'Hydro-electric Installations of India'. This latter installation could be utilised to provide power for the manufacture of aluminium as bauxite exists in Jammu province. For the preparation of aluminium, large currents are required, as high temperatures (900 degrees centigrade) must be used to dissolve alumina in cryolite. 'A current density of about 1.5 ampere per square inch of cathode surface is usually allowed and about 12 h. p.-hours are required to produce a pound of metal'. The anode is of carbon which is attacked by the oxygen liberated as the result of electrolytic action when current is passed. To get an idea of a low-head lay-out applicable to the existing Jammu installation and for other illustrations, please see H. E. I. I.

Table No. 10 gives imformation tabulated from the Return compiled upto the 30th of August 1933, kindly supplied by the Chief Engineer.

Detailed descriptions with illustrations of the Plants are given in chapters 3 and 4 of 'Hydro-electric Installations of India.'

TABLE NO. 10.

Water-power stations of Jammu and Kashmir.

Installation	Generating Stations		Kashmir Receiving Stations				
	Jammu	Mohora	Srinagar	Baramula	Gulmarg	Doabgah & Sopur	Pattan
Date Supply began	1909	1909	1909	1914	1917	1918	1929
No. of Consumers	3900	285	14700	1940	300	1630	265
H. P., motors	580	100	880	200	...	80	8
Max.-Load recorded, kilowatts	500	2800	2200	Street lamps 14	...	...	...
Total Kilowatts connected	...	5000	3020	155	186	85	30
Substations	21 ; 782 kVA	Transformers	1;3000	1;600 kVA	1;400	1;600	1;400
Transformer Stations.	...	6;1000kVA	46;3180	5;170	5;186	4;155	3;30
Output for year (units)	2,581,660	17,993,375	...	Population 6510		Population — 10704	...

The voltages for consumers are 220 volts single-phase in each place but three-phase is 3000 volts 50 cycles at Jammu and 2200 volts 25 cycles in other places except at the generating station where it is 2300 volts, for obvious reasons.

The rates for lights are as follows:—

6 annas per unit or 11 as. per month for 20-watt lamp. (In Kashmir).

6 annas per unit or 9 as. per month for 20-watt lamp. (In Jammu).

4 annas per unit for a combined lights and fan installation in Jammu.

Re. 1/- per month for a 20-watt lamp in Gulmarg.

Flat Rates for fans vary from Re. 1/- to Rs. 2/4 per month according to capacity.

Flat Rates for fans; Rs. 4/8 for ceiling fan, Rs. 3/8 for table fan in Jammu.

The rates for power are as follows:—

2 annas per unit, the same for heating.

Rs. 90/- per H. P. per year for 12 hours per day; Rs. 120/- for 24 hours' supply per day.

The following notes about the Kashmir Installations are from Garckes '*Manual of Electrical Undertakings, 1933-34*:—

(1) Jammu.—Capacity 1200 kW.-Four generators, two 350 kW, one 340 kW and one 160 kW., 3000 volts (N. B.; C. E. says, two 186 kVA besides two 350 kVA. Not more than 3 sets are run at one and the same time). Substations, including industrial, 21.

(2) Kashmir.—(a) Mohora, Flume, 560 cusecs. Plant, four 1000 kW; ultimate capacity 10,000 kW. Line voltage, 30000/60000 V. Overhead to Srinagar, 54 miles and Baramula, 21 miles, at 30,000 V at present.

(b) Baramula substation for Baramula, for Doabgah and Sopur and for Gulmarg.

(c) Srinagar; Receiving Station, 3000 kW. Industrial installations, 121.

Rate for supply of power:—(a) 6 annas per unit for lighting, meter hire 12 annas per 10 A capacity meter.

(b) Flat rate, 11 annas to Re. 1 (see the last page for other details). Current limiters are used for this kind of supply and a rent of 5 annas per limiter is charged.

N. B.—The Jhelum Power Installation is capable of developing 20,000 horse-power, which could be utilised for electric railways or electro-chemical processes or other industrial operations. When it was started, a good amount of the power was used for dredging operations at Baramula.

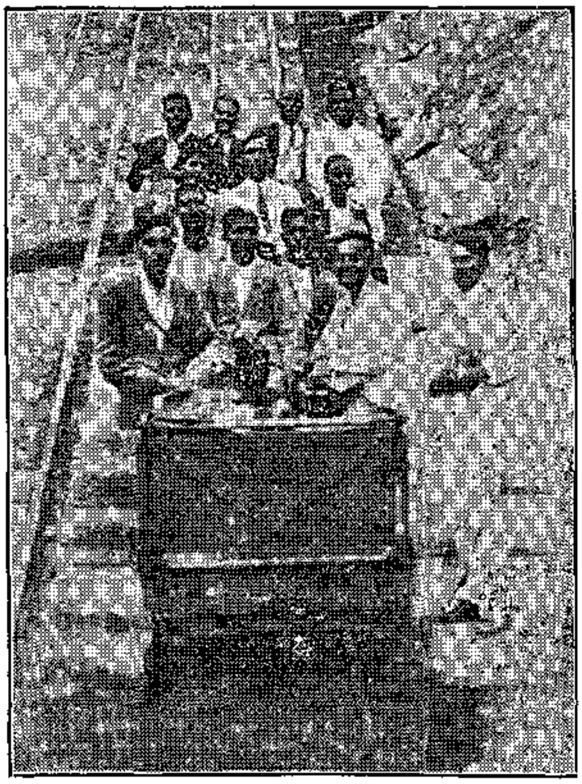


Fig. 9. Electric-motor-driven Rope Trolley.
Poona College Students, D. E. E. Class, 1928–29.
SIVASAMUDRAM.

CHAPTER VI

TRIUMPHANT TATA TRIO OF WATER POWER PLANTS.

The most noteworthy of the hydro-electric installations in the Bombay Presidency, in fact in the whole of India, are those of the Tata group of hydro-electric power supply companies, who have harnessed the Rainfall on the Bhore Ghat between Bombay and Poona. The first of these companies, named the Tata Hydro-electric Power Supply Co., utilises monsoon precipitation stored in 3 lakes and has been fully described in the Chapters V and VI of H. E. I. I., pages 62 to 111; the second is styled the Andhra Valley Power Supply Co. and its license can be seen on pages 292 to 296 of the same book, which also contains 15 large-sized illustrations pertaining to these schemes; the third which is called the Tata Power Co. is alluded to but not described in H. E. I. I. as it had not been taken in hand at the time H. E. I. I. was published. Particulars of the three undertakings, kindly supplied by the General Manager, Mr. B. P. Sethna, are given in Tables Nos. 15 and 16. The reader can thus see at a glance what the various hydraulic and electrical quantities pertaining to the plants and systems of the Tata group are and by turning to H. E. I. I., a comparison can be drawn between the present and the past, and the extent of the progress made can be gauged.

Special attention should be paid to facts and figures relating to the Nila-Mula River Project with Head-works at Mulshi and power house at Bhira, belonging to the Tata Power Co., the last and largest member of the Trio. The great 300,000 h. p. Koyna Scheme, of which a brief mention was made on pages 93 and 94 of H. E. I. I. has not yet materialised. The lay-out of the Tata Hydro Co's. hydraulic works, that of the Andhra Co. and the power transmission line from Khopoli to Bombay may be seen in H. E. I. I. Figs. 14, 26 and 20 respectively. The power stations of these two companies are situated at Khopoli and Bhivpuri respectively, both not far from the G. I. P. Ry. station, Karjat. The power house of the Nila-Mula

scheme is however far from the railway line, being near Roha, in the Kolaba district, not far form the sea-coast;- the headworks are at Mulshi in the Poona district, also away from the railroad. One of the large illustrations accompanying this chapter shows not only the Lakes of all the Tata companies but also other important lakes and reservoirs for power or irrigation, including the Koyna and the Bhatghar Lake,-the latter was mentioned in Chapter VIII of H. E. I. I. describing the Bhatghar Dam Hydro-electric Installation. The three lakes of the Tata Hydro-electric Power Supply Co. are however better seen in Fig. No. 13 of H. E. I. I. The Kundli Valley extension referred to on page 261 of that book has not turned out to be a success.

Figs. Nos. 13 and 14 of this Chapter show respectively (1) the location of the lakes, etc. and (2) the manifold-pipe or penstock-head at the top of the Ghat. Gibbs or Andhra Valley Lake, formed by Thokarwadi Dam, is 12 miles long at R. L. 2195, rainfall averaging 130 inches per year.

TABLE NO. 11.

Tata Hydro-Electric Dams and Lakes.

Name of Dam	Height of Roadway above River-bed (Ft.)	Contour R. L. above mean sea-level (Ft.)	Contents to contour Million Cub. Ft.	Power ex. Turbines Million HP-hrs.	Outlet level (Ft.)
Shirawta	92	2159	7102	296	2084
Walwhan	70	2086	2690	112	2034
Lonavla	34	2051	361	15	2034

The Khopoli and Bhivpuri power plants are electrically tied together by power lines at their generating as well as at the receiving ends. The Tata Power Co.'s Generating Station at Bhira is to be shortly linked with the Khopoli Power Station of the Tata Hydro-Electric Co. The three concerns work in close co-operation, sharing the load in Bombay and helping one another as and when necessity arises, though the accounts are kept separately. The financial success of these hydro-electric projects is apparent from the following statistics of units of energy sold and of the revenue realised, per annum for the septennium ended 1934 ;—

TABLE No. 12.

Year.	Units Sold			Revenue in Rupees.		
	Hydro	Andhra	Tata Power.	Hydro	Andhra	Tata Power.
1927–28	114,002,131	117,772,319	87,526,346	45,43,456	52,30,464	35,35,223
1928–29	102,226,164	114,001,399	109,735,843	40,63,704	48,69,921	44,10,903
1929–30	117,158,874	136,588,111	139,153,876	45,79,667	55,44,158	55,13,985
1930–31	120,000,000	133,003,354	140,479,501	47,96,823	53,55,910	54,96,118
1931–32	120,000,000	160,000,000	144,580,706	48,06,217	62,30,687	57,00,966
1932–33	120,000,000	154,390,758	138,793,256	50,54,000	56,34,000	55,17,000
1933–34	94,429,897	136,133,026	146,985,524	37,96,983	54,76,788	57,64,331

Noteworthy events during the decennium are as follows :—

(a) Bombay Electric supply and Tramways Co. and the B. B. & C. I. Ry. and G. I. P. Railway receive their bulk supply of electrical energy from the Tata Power Stations,—the B. E. S. & T. Co.'s demand being about 90 million units. However, the G. I. P. Ry. main lines from Kalyan to Poona and from Kalyan to Igatpuri depend upon their own 49,000kW steam-electric station at Thakurli or Chola near Kalyan, which generates power at the same high voltage as the Tata generating stations do but transmits it to 11 sub-stations located at intervals of about 12 miles along the railway line. The railway sub-stations change the current from alternating to direct and lower the pressure to 1500 volts at which the train-motors and electric locmotives work. Out of the 150,000 h. p. required for the Bombay textile mills, nearly 120,000 h. p. is supplied by the Tata hydro-electric group.

(b) The amount of masonry in their five dams is 54 million cu. ft. Shirawta Dam alone has over 16 million cu. ft. The amount of masonry in the Tata Power Dam at Mulshi would, it is said, suffice to build a wall, 2′ 6″ thick and 6 ft. high, from Bombay to Jamshedpur across the Peninsula. The dams of the Andhra Valley and Tata Power companies are built so as to be capable of extension,

The dams are all of solid masonry set in Deccan trap rock, supposed to be impervious to leakage.

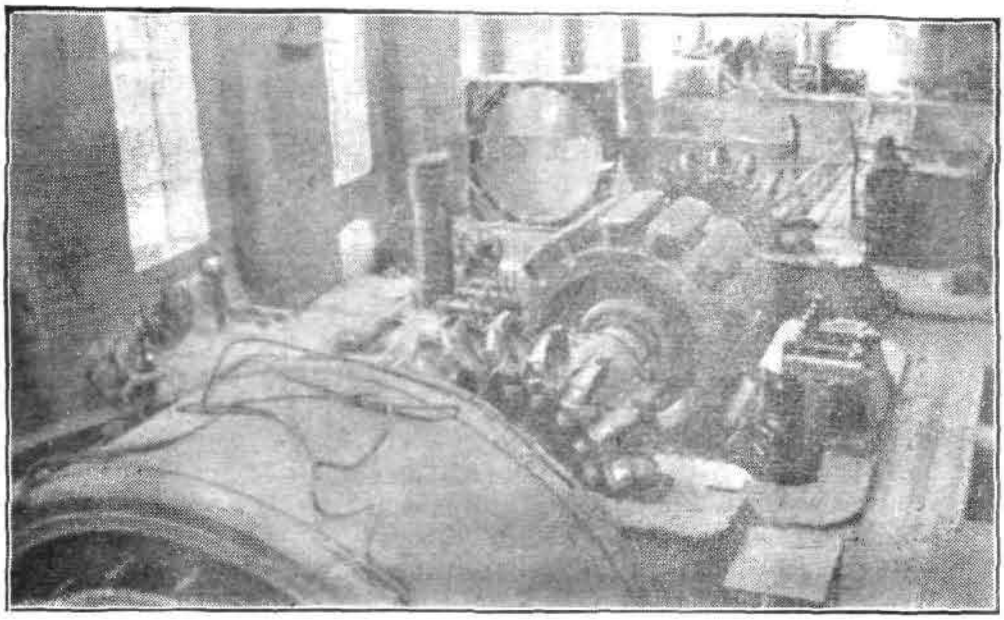


Fig. 10. Tata Power Alternator, BHIRA.

The Dams at Shirawta and Walwhan for the Willingdon and Sydenham Reservoirs respectively and the Forebay Dam at Khandala, which had begun to 'sweat' have been subjected to "cementation" which has succeeded in stopping all bad leaks. The Shirawta Dam contains 17 million cubic feet of masonry and the leakage from this had attained the formidable figure of 22 cusecs in 1931. After drilling and injecting cement by compressed air supplied from electrically-driven compressors, the leakage has been reduced to 2.84 cusecs only. 5400 tons of cement was consumed in the process, vide Atherton's Paper on *Cementation* before the Bombay Engineering Congress, 1932. The waste weir of Shirawta Dam has been lowered by 3 feet over a distance of 750 feet.

(c) Not only are the mills, factories, tramways and railways of Bombay now getting their bulk supply from the Tata Group but also Electric Supply Companies of the following places :—Bombay suburbs, Thana, Lonavla, Khandala, Kalyan, Poona and Panvel. A few figures regarding these Companies are given in tabulated form below :—

TABLE NO. 13.

Company.	Year	Installed Capacity (kW)	Remarks.
B. E. S. & T.	1924–25	42,000	N. B.—The mills and factories of Bombay take power equal to about 100,000 h. p. and the B. B. & C. I. and G. I. P. R. take about 38,000 h. p.
Bom. Suburban.	1928	950	
Thana.	Oct. 1928	200	
Lonavla-Khandala.	June 1929	100	
Kalyan.	Oct. 1919	250	
Poona.	Jan. 1930	4,000	
Panvel.	Nov. 1930	430	
Bhiwandi.	1932	100	

The Bombay Suburban Co. purchased about 1.386 million units in 1932, 1.53 million in 1933 and 18.3 million in 1934. Several improvements and alterations have been made in the management, administration and equipment with a view to effecting economy and increasing efficiency. The Poona City Supply Co. is earning about Rs. 2 lakhs per annum. Extensions of this Company in their Receiving Station and Area of supply are about to be made, as it is a progressive concern. Some of the existing H. T. lines of the Tata Companies have been realigned. All lines are protected with overhead ground wire throughout. H. E. I. I. Fig. 20 shows the route of the transmission line from Khopoli and Bombay and the region through which it passes. If the main-line railway substations (not only towns along the G. I. P. Ry.) decide to take their requirements of electric power from the Tata Groups, considerable extensions of the plants, lines and accessory equipment will have to be undertaken. While the town-demand is welcome, it is small compared with the steady and large demand for power of the railways which have been electrified. A few illustrations relating to the Andhra Valley Company's works are appended hereto; fourteen illustrations pertaining to the Tata Hydro-Electric Company's plant and system have already been published in *Hydro-Electric Installations of India*; at other places in that book occur illustrations of plant similar to that of the Tata Power Company, though not so large as of this undertaking which takes the pride of place among existing water power plants of India. The hydraulic portions of the Tata Power Co.'s plant include the tunnel for water from Mulshi Lake with sluice gates at Dandi and pipe lines; manifold for 3 pipes and valve house for 6 pipes at Dongarwadi, lower down each bifurcating into two pipes for one hydraulic turbine. Figs. 10 and 11 pertain to the Bhira power station

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Fig. 11 shows the Bay wherein the Transformer Banks are installed inside the building. Fig. 10 shows the interior of the same station, the left-hand portion being of special interest because in this photograph one of the sets–a water wheel with its electrical companion, the alternator–are shown with the outer covers removed, thus showing the rotating portions of the two machines of the set. Fig. 12 shows the Control Board of the power station at Bhira. In the Bhira power house are installed five 27,000 h. p. water-wheels and 17,500 kW alternators complete with the accessories, starting wheels, oil

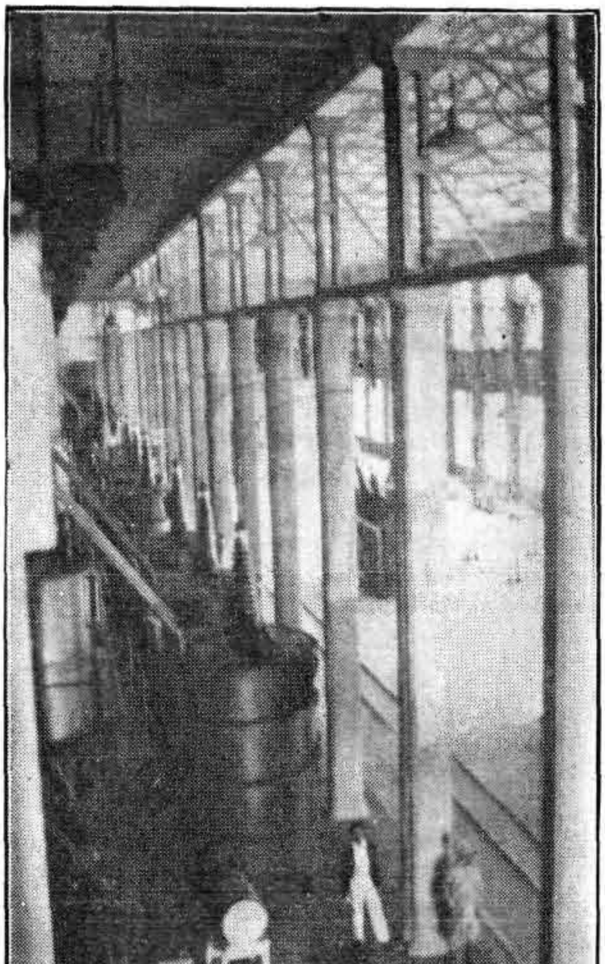


Fig. 11. Tata Power Transformer Bank.
BHIRA.

governor etc. etc. Another set of the same size could be installed, when the demand for it is felt. The full particulars of the alternator are as follows:—17,500 KW, 11,000 volts, 1150 amps, 375 r. p. m. 16 poles, 50 cycles per second, 0.8 power factor, 20 per cent. overload for 8 hours. The high-tension compartment of the Bhira Power House contains 12 transformers, each rated at 10,000 kVA, connected in Delta-Star, stepping up voltage from 11,000 to 110,000 volts, for transmission to Dharavi, near Matunga in Bombay, where there is a Receiving Station for both the Andhra Lines from Bhivpuri and the Tata Power lines from Bhira; for details, please turn to the end of this Chapter.

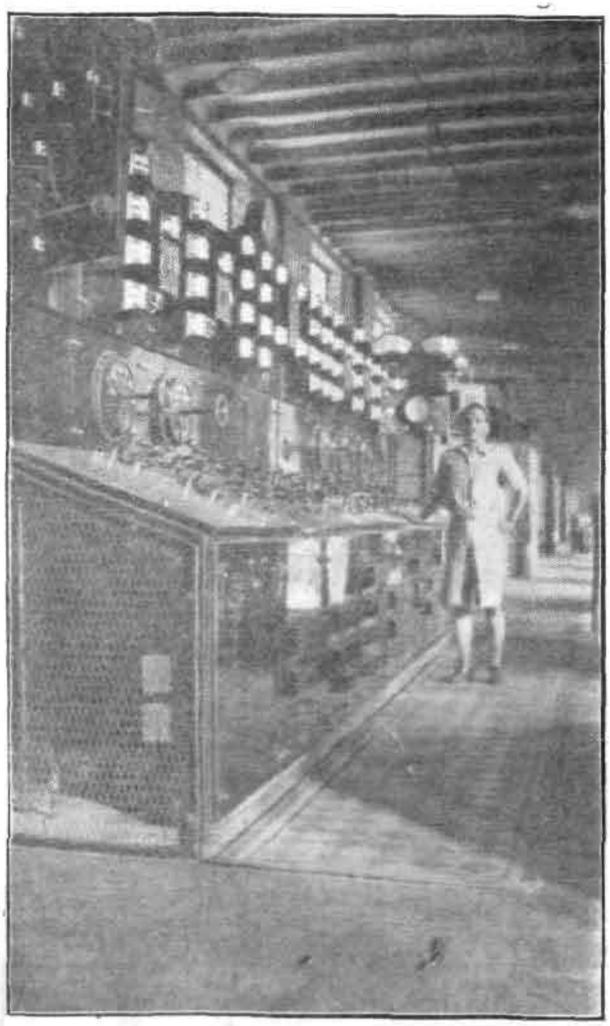


Fig. 12. Control Board or Bench Board, Tata Power station. BHIRA.

Of the six generating sets installed at Khopoli, four are Escher-Wyss–Siemens Schuckert and two English Electric–General Electric combinations;–the size can be gauged from the fact that the diameter of the alternator is 18 feet. The equipment installed at Bhivpuri is similar in size and nature to that of Khopoli plant, but the Bhira units are more than double in capacity. Three lines from Khopoli go to Bombay, two to Bhira, two to Poona and one to Bhivpuri. Distances are given in Table No. 16: the line to Poona is 48 miles long. The following extract is from Garckes' *Manual of Electrical Undertakings, 1934*, pages 1574–75 and 1625–28 :—

TABLE NO. 14. *Tata Schemes Supply Statistics.*

Company.	Consumers.	Power.	Output.	Prices charged.
Andhra Valley	37	62000 H. P.	160,000,000	As given below.
Tata Hydro	47	,,	120,000,000	,, ,, ,,
Tata Power	...	...	144,580,000	,, ,, ,,

For *Textile Mills.* For 500,000 units and upwards per annum, Rs. $3\frac{1}{2}$ per month per kW of maximum demand, which payment entitles consumer to use without additional charge 35 units for each kW upto 1,150 kW and 70 units per kW in excess of 1,150 kW, plus 0.50 anna per unit for next 200,000 units used per month and 0.40 anna per unit for all additional units used per month. Lighting charge, 1.25 anna per unit.

Factories other than textile mills (using 500,000 units and upwards per annum) Rs. 4 per kW of Maximum demand, which payment entitles consumer to use 15 units for each kW upto 100 kW and 45 units for each kW in excess of 100 kW, plus 0.60 annas per unit for next 65000 units used per month and, 0.45 annas per unit for all additional units used per month. Lighting charge, 1.25 anna per unit.

In both cases the consumer may at his option use upto 20 p. c. of the total energy supplied for lighting his premises. The Maximum demand must not be less than 85 p. c. of Maximum demand occurring during previous 12 months.

Resale rate for lighting and power outside City and Island of Bombay. Maximum demand charge of Rs. 4 per month per kW of Maximum Demand plus 0.8 annas per unit for first 15,000 units per month and *0.5 annas per unit for all units used per month in excess.* "A population of approximately 16 lakhs residing in areas totalling 350 square miles are now receiving from the Hydro-electric System general power service, including railway electrification" Bombay–Poona, Indian Science Congress, 1934. "There is sufficient water storage capacity to allow for extensions to the generating plant to meet the present and future requirements of Bombay City, its suburbs and the areas through which the lines now run."

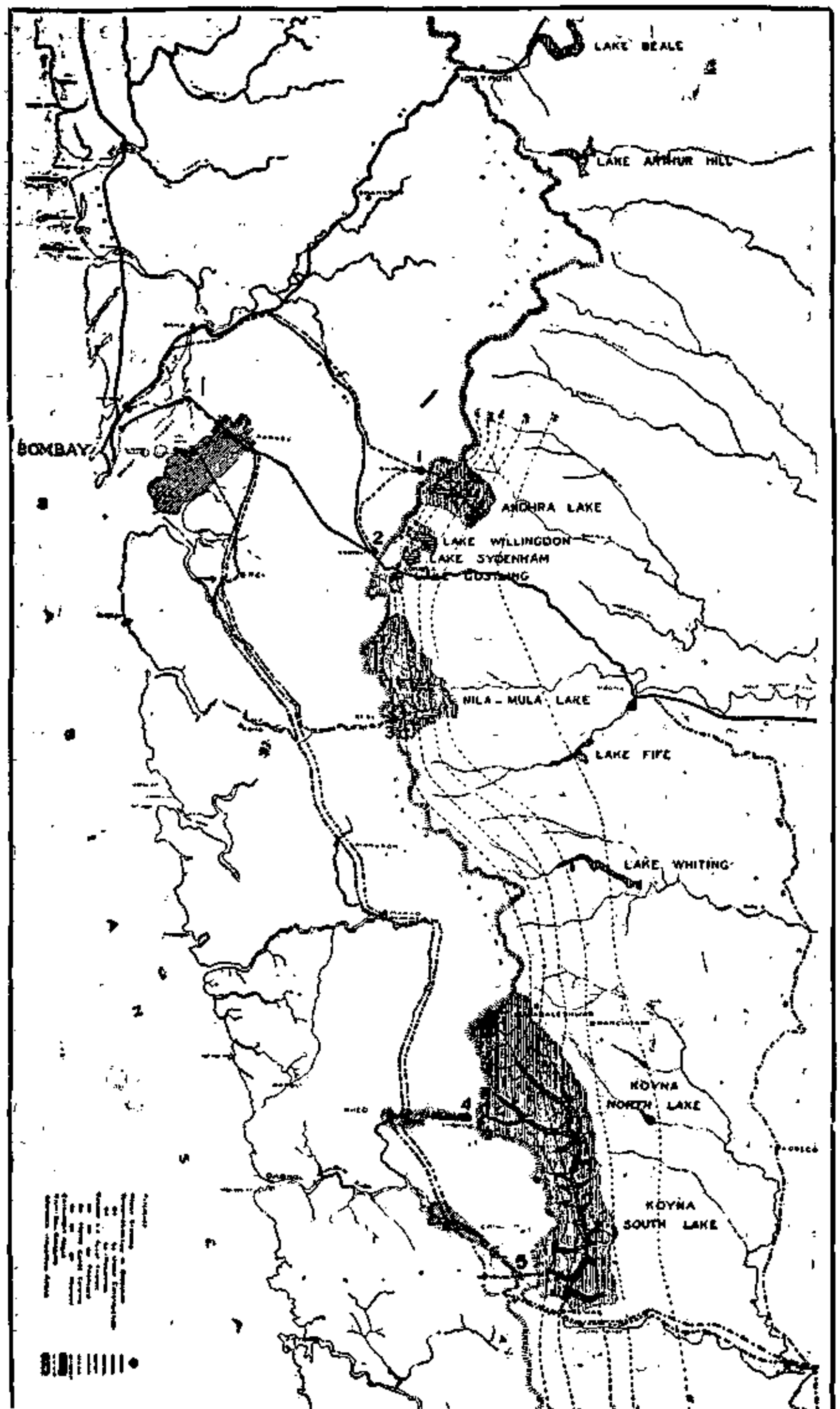


Fig. 15. Location of Tata Water-Power Lakes.

TABLE NO. 15.

Tata Hydro-Electric Schemes. Particulars of Main Features. Hydraulic Data.

Serial No.	Item.	Hydro-Electric Co.				Andhra Valley		Tata Power
		Willingdon	Sydenham	Gostling Lake		Thokarwadi near Sate G. I. P.		Mulshi Dam.
		Shirawta.	Walwhan.	Lonavala Dam.		Lake Gibbs.		Nila-Mula R.
1	Catchment Area (sq. miles).	11	5.5	5.4		48		95.6
2	Area of lake at F. S. L. (sq. miles).	5.05	2.4	1.5		12.5		14.85
3	Capacity above Draw-off Level (Million Cu. Ft.)	6567	2560	414		12850		16120
				Main.	Aux.	Main	Auxil.	
4	Length of Dam (Feet).	7607	4450	3615	1725	2432	2200	5123
5	Section of Dam at top.	12	13	14.5	17.0	15	5	18
6	„ „ bottom.	51.2	40.8	17.5	17.0	148	15	108
7	Height of Dam above River Bed (Feet).	83	71	34.5	22	190	17	146
8	Length of Waste Weir (Feet).	1206	1130	644	1000	557	...	1503
9	Length of tunnel (Feet).	5000				8700		14850
10	Section of tunnel (sq. feet).	93.5				82		140
11	Length of Duct line (Feet).	22850				...		...
12	Area of Duct (sq. feet).	189 and 150 (480 cusecs)						
13	Pipe lines and Penstocks (Nos. and Diam).	2×82½/72" 6×42/38"				6×42", 6×38"		3×84"; 5×58/52"; 10/36"
14	„ „ Length of Each.	2 each 8200'; 6 each 4300';				6×2310'6; 2296'		3; 140': 5; 3670': 10; 2070'
15	„ „ (Wt. in tons).	9700				6000		7500
16	Max Head (gross).	1726'				1743'		1650'
17	Min: „ „	1694'				1670'		1601'

TABLE NO. 16.

'Tata Water-Power Trio.' Electrical Data of Stations.

Serial No.	Item.	Hydro Khopoli.	Andra Bhivpuri.	Tata Power. Bhira.
18	Generators (No. and kW.).	6 ; 8000 (1 ; 8000)	6; 8000 (1; 8000)	5 ; 17500 (1 ; 17500)
19	Total K. W.	48000 (8,000)	48000 (8000)	87500 (17500)
20	Generator Voltage.	5000	5000	11000
21	Step-up Trans-former (No. and kVA).	15 ; 3333 1 ; 10000	9 ; 8000	12 ; 10000
22	Voltage Ratio.	5000/100000	5000/100000	11000/100000
23	Transmission Lines. (Voltage).	100,000	100,000	110,000
24	" (No. of E. H. T. Circuits and route length in Miles.	2×43	2×56	2×76
25	Tie-line between Khopoli and Bhivpuri.		1×18	(22000 V circuits 25 miles)
26	Tie-line between Hydro and Andhra Receiving Stations at Parel and Dharavi.	1×7		
27	Towers (No.).	4—legged 478	latticed steel 596	painted 2×830
28	Normal Spacing.	500′	500′	500′
	Maximum Spacing.	1175	1175	1175
29	Copper Conductor Area (Sq. in.).	.095	.095	.095
	Aluminum (Sq. in.).	.1045	.1045	.1045
30	*Receiving Station.*	Parel.	Dharavi.	Dharavi. | Kalyan. | Poona.
	Transformers Step-down (No.).	15 ; 6	(Δ–γ) 9	(Δ–γ) 12 | 3 | 4
31	" (kVA each).	3120 ; 4.000	7000	9000 | 4000 | 1000
32	Voltage (L. T.) (H. T. 90,000).	6600 ; 22000	22000	22000 | 22000 | 3300
33	Synchronous Condensers.	4 of 16000 kVA total	2 of 25000 kvA total	2 of 25000 kVA total
34	Underground Cables.		175 miles.	

Fig. 14. Andhra Valley Penstocks, at the top of the Ghat.

TABLE NO. 17.

Transformer Data of Electrical Undertakings receiving Bulk supply from the Tata Group, (Culled from Details kindly communicated by the Electrical Engineer to Govt. of Bombay).

Name of Scheme	Particulars of Transformers (E. H. T. or H. T.)					
	Number	Voltages		Type.	Kilovolt-amperes of each.	Year of Installation.
		H. T.	L. T.			
Bombay Electric	4	22000	5500	G. E. C.	7500	1924,1926
Supply and Tram-	2	„	6600	„	1750	1917
ways Co.	2	„	„	„	250	1928
Bombay Suburban	2	11000	400	...	50	1927
Electric Supply	2	„	„		100	1928
Co.	6	„	„		50	1929
	2	„	„		„	1930
	1	„	„		100	„
	1	„	„		„	1931
	1	„	„		50	„
Salsette Feeders	1	22000	11000		850	
	2	„	„		375	
Poona Electric Supply Co.	4	90000	3300	I. G. E. (Oil)	1000	1931
Bhiwandi E. S. Co.	2	...	...	...	80	1932
Thana E. S. Co.	2	22000	400	I. G. E.	100	1928
Lonavla-Khandala E. S. Co.	2	4400	„	A. E. G.	50	1929
(Kalyan Substation	3	90000	22000	(Oil)	4000	Tata's)
Kalyan E. S. Co.	2	22000	400	„	125	1929
Panvel Taluka E. D. Co.	2	„	„	A. E. G.	200	1930
Panvel Taluka E. D. Co.	1	„	„	Siemens	30	1931

The following excerpts supplement information given in Chapters V and VI of *Hydro-electric Installations of India*, particularly pages 107 and 292-6. *Andhra Valley Project, Supplementary Information* (Extract from Mr. J. F. Heath's Paper, see Vol. III, April 1923 of *The Institution of Engineers* (India)): (Hydraulic and Electrical Data of this Project are given in Tables 15 and 16 along with similar data for the other Tata Hydro-electric Schemes) :-

"The surge chamber, near the outlet of the tunnel, is 15 ft. in diameter. The manifold pipe is for the purpose of connecting the

tunnel single outlet with the 8 penstock pipes. It extends into the tunnel 40 ft. for joining thereto with concrete filling; baffle steel rings are riveted to the pipe at 6 ft. spacing to prevent any water creepage and to ensure the pipe being well bedded in the concrete. Outside the tunnel, the manifold extends 85 ft. and tapers from 10 ft. to 5 ft. in diameter with four branch pipes of 42" diameter on either side. The branch pipes lead from the manifold pipe to the top of the hill where the controlling valves are situated. The weight of the manifold header pipe is 54 short tons.

The efficiency of the turbine is 85 p. c. at 12000 h. p. *ex* turbine. The speed is 300 r. p. m. The generator is 10000 kilovolt-amperes. The present capacity is 60000 kVA with provision for an extension of 20000 kVA. The generators are cooled by forced air draught through a main air duct running from end to end of the Power Station. Each transformer bank has a capacity of 24000 kVA., the present installation comprising 72000 kVA. The banks are connected delta on the primary and Y on the secondary (100,000 volts) side, with neutral point earthed. Two lines go to Dharavi Receiving Station, Bombay and one tieline to Khopoli. A 3rd line to Dharavi may be installed. The proposition is for 3 lines of Tata Power Co., 3 of the Andhra Valley Co., 1 tieline to Tata Hydro Co's. station, and 1 spare line, making provision for 8 circuits.

The weight of steel in an intermediate Tower is 4932 lbs. Special Towers over the Thana Creek Crossing give 80 ft. clearance between the power lines and H. S. L. The sag for this (span) is 26 ft.

N. B. Brief mention is made above of the Dharavi Receiving Station. This is connected electrically with the Tata Hydro Co.'s Receiving Station at Parel in Bombay. The latter gets its power from Khopoli. The power for use in Bombay from both the Bhivpuri Power House of the Andhra Co. and the Bhira Power House of the Tata Power Co. is received at Dharavi Station near Matunga. Some particulars of all the stations are given in Table No. 16. The Parel Station was described with illustrations in Chapters V and VI of H. E. I. I. Other particulars of the Dharavi Station are given below:—

The two sides in the Dharavi Station corresponding to the lines from the two power stations are joined through two sets of 3 single phase 541 kVA reactors on the 22,000-volt bus-bar through switches. The main water-cooled transformers for both the Lines are connected delta-Y, but the arrangements for cooling the water after it has passed through the transformer cooling coils are different, one arranging to trickle the water down a tower, the other shooting up in sprays

through jets. There are 3 station transformers, each of 100 kVA, for stepping down from 22,000 V to 229 V. Each of the 4 synchronous condensers has 12 poles and runs at 500 r. p. m. Their bearings are lubricated by forced oil and cooled by pumped water, kept cool by circulation. Their poles are fitted with short-circuited bars to enable them to be started as Induction motors at 7,000 V though the normal voltage while running is 22,000 V. Each of them has its own exciter. Tirrill Regulators maintain the voltage constant by keeping the excitation steady.

Protection against line disturbances is made by installing static dischargers on the 22,000 V side and oxide-film arresters on the 100,000-volt side. Telephone instruments and operators are protected by providing drainage and insulating coils to earth between the telephones and the telephone lines which are liable to have large voltages induced in them because they run parallel to the H. T. power lines. The latter are transposed at intervals to safeguard against unbalancing due to mutual inductance. The usual relays, alarms and indicators are provided in the Station to protect the electrical machines. Transformers are kept cool by bathing their coils in transil oil, which is circulated through ducts vertically, horizontally as well as across the cores.

TABLE NO. 18.

The following figures apply to the Tata Hydro Group (Science Congress Book 1934.)

Total Capital Cost Rs. lakhs.	Service Capacity of present storage KW-hrs.	Average Annual Consumption kW-hrs.	Load demand during year ending June 1933.	Population of area served, lakhs.	Consumption per capita per annum.	Ratio of Hydro power to existing power demand.
1567	580 millions	404 millions	131500 kW	16	252 kW-hrs.	70 per cent.

It is expected that in 1941 the three Tata water power concerns will be amalgamated when the existing debentures will reach their maturity and the plants their present limits.

CHAPTER VII

GOKAK FALLS WATER POWER PLANT.

The Gokak Falls Plant is fully described in Chapter VII, pages 112 to 123, of ' *Hydro-Electric Installations of India.* ' The machines were supplied by ' *Maschinen fabrik Oerlikon bei Zurich.* The generating sets are of the vertical-shaft or umbrella type, with the turbines right at the bottom and the alternator and exciter at the top. For lighting the station, a 14 h. p. Pelton wheel is started to run a dynamo and a 3 h. p. 110V D. C. motor runs a pump. At the bottom floor, where leakage water collects, a 3 phase 440 V15. 4A motor drives a bilger pump. Six Static Condensers have been installed, outside the mills on the hill-side not far from the Falls, to improve the power factor. Each of the condensers is rated at 124kVA 460V 60 cycles per second. In the steam standby station situated near the supply-channel and the pump house, there are installed 2 A. E. G. alternators, one of which is normally run. It is rated thus :— 1,390 kVA. 1040kW, p. f. = 0.75, frequency = 50; 3000 r. p. m., 1750 amps, 460 volts. The exciters are Crompton Shunt Wound D. C. Generators rated at 22kW., 960 r.p. m., 110 volts, 200 amps. The motor driving the exciter is a 30 h. p. 1440 r.p.m. 3-phase 50 cycle 440 volts induction motor. The aggregate capacity of the plant installed in the Hydro-Electric Installation is 4500 horse power approximately. Three turbines are rated at 900 b. h. p. each and the fourth double as much, the respective alternators being 650kVA and 1300kVA. No hightension transformers are employed, as the bulk of the load is within a furlong of the Falls, where the source of power is installed. Six Illustrations relating to the Gokak Falls have been printed in Chapter VII of ' *Hydro-Electric Installations of India* '. Two new views are shown here, one being of a vertical turbo-alternator while the other shows meter stands and machines; see Fig. No. 15 and Fig.

No. 16. A vertical section of the Power Station and of the plant installed in it may be seen in H. E. I. I. Fig. 31.

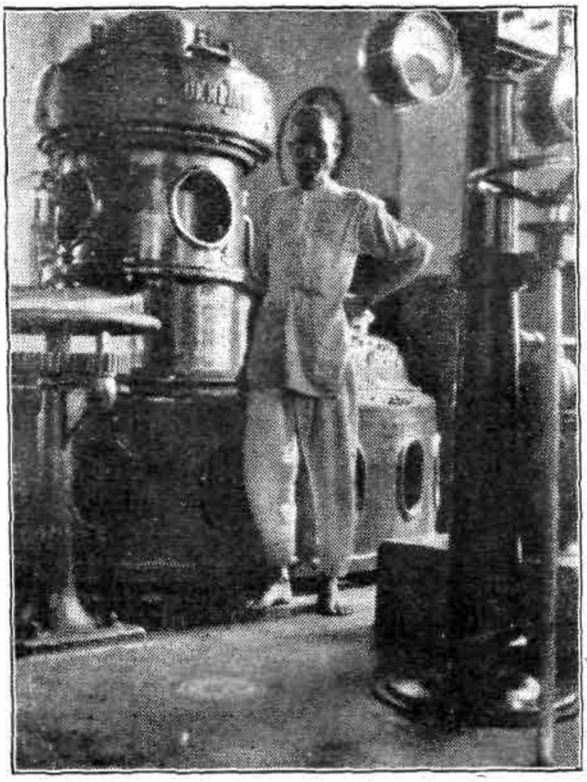


Fig. 15. Vertical Alternator.
GOKAK FALLS.

An automatic voltage regulator is provided for maintaining the voltage constant at the desired pressure. In the vertical - shaft sets, the a. c. generator is below and the d. c. generator on the top of it. Besides the main generating sets, there are two smaller 50kW. sets which may be used either as turbogenerators producing d. c. for the excitation of the fields of the alternators or as inverted rotary converters for generating alternating current, independently of the water turbine. When used as a rotary converter, the machine normally acting as exciter can work as a generator to give 60kVA 460 volts 3-phase current at 50 cycles per second. On certain days when the mills are not working and load is small, the small sets can be run by their turbines to supply both a. c. and d. c. for pump-motors, lights, and controlling devices. The instrument stands are installed near each set (not concentrated at the switch-board as is the standard practice). The other sketch pertaining

to this plant is Fig. 29 of H. E. I. I. and shows among other things, the electrically-operated outdoor swing crane which is a useful and unique adjunct of the equipment. In this illustration are seen the relative position of the river, supply channel, pump house, penstock, power house, falls, suspension bridge and mills. The following note about the Gokak Installation is from Garckes'

'*Manual of Electrical Undertakings, 1934*':—

TABLE No. 19.

Gokak-Falls Data.

Ghataprabha, Minimum perennial flow...136 cusecs.

Regulating storage...1100 million cubic feet.

Length of pipe-line...275 feet.

Working head...210 feet.

Plant installed...1,570*kVA (Now 1300kVA more).

The Western Ghats of the Bombay Presidency present similar geographical features to those of the Southern Appalachians of the U. S. A. where 'the elevation of the plateau near the coastal plain ranges from 300 to 600 feet and towards the western margin, hills rise higher and higher above the general plain until they develop into small mountains, some of which have an elevation of between 2000 and 3000 feet; a series of waterfalls occurs where the streams cut back from the soft deposits of the coastal plain into the hard rocks'—(Like the waterfalls at Gokak, Dudh Sagar etc.). The Eastman or Kodak Co. have a classroom film on the subject of what electric power in the southern Appalachian region has done for its people. Continuing the note quoted above from the Guide to this film :—' The falls furnish power for many factories; the utilization of the power for manufacturing purposes has stimulated industrial development of this region. Cotton-textile mills have been established which utilise the cotton grown in the South (as at Gokak Falls); the development of electric power has changed living conditions; the electric light has lengthened the day for work and leisure activities. The electric iron, electric washing machine and other labour-saving devices have been introduced; industrial development has stimulated the building of good roads; these roads break down the barriers of isolation thus

* 3 sets each of 650kVA=1,950kVA. Total capacity 3,250kVA.

increasing social intercommunication; good roads have facilitated the marketing of farm products; an abundant supply of timber has made the making of furniture an important industry' :— this may become true of the region round about Dudh Sagar, if ever that waterfall is harnessed, as adumbrated in the next chapter.

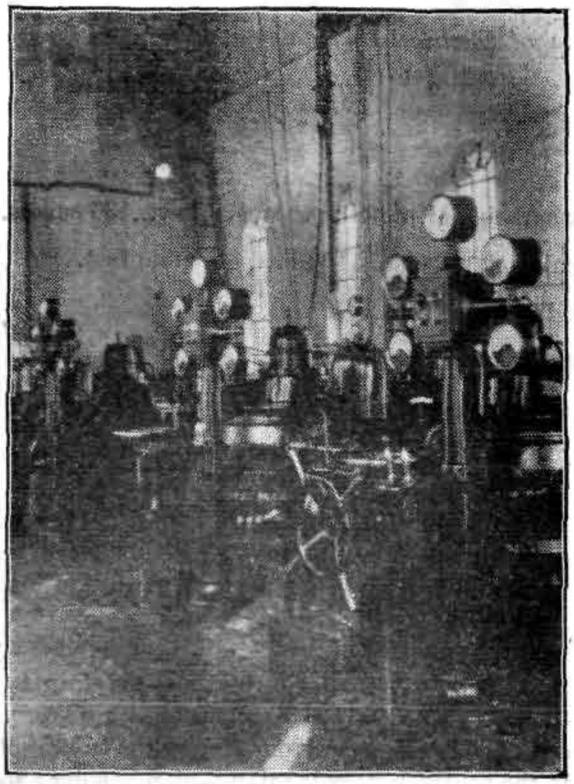


Fig. 16. Meter Stands and Machines;
Power House: Top floor.
GOKAK FALLS.

CHAPTER VIII

OTHER WESTERN INDIA WATER POWER PROJECTS.

As in the South of India, the Mysore State was the pionee in the matter of hydro-electric development, so in the middle west of the Peninsula, the firm of Tatas led the way in this matter in 1915 when their first station started functioning. Another water power plant in the Bombay Presidency is the one at Gokak Falls, but it was not electrified till 1913 though power from the fall of water had been obtained there as long as 1886. Whereas the Gokak Falls Installation is located right at tha base of the natural Falls, the Tata staions derive their supply of water through long penstocks and tunnels from huge reservoirs, artificially created and dependent largely upon monsoon precipitation, not upon perennial rivers. A small hydro-electric installation also exists at the down-stream side of the Dam at Bhatghar, about 32 miles from Poona, which city however does not receive its electricity supply from Bhatghar, as was suggested at one time but from the farther Tata Station at Khopoli which generates power at a much higher voltage. The Bhatghar Dam possesses the distinction of having not only power pipes but also electric thermometers with horizontal connections and a vertical shaft through it, — the former to measure temperature changes, the latter deflection when loaded.

The *Bhatghar* Installation is described in Chapter VIII of '*Hydro-Electric Installations of India*'. It will now extend the scope of its transmission by delivering power to the capital of Bhor State which is about a couple of miles from the Dam at Bhatghar. The accompanying illustration kindly given by the *Times of India*, Fig No. 17, shows the relative location of Bhor, Bhatghar, Lake Whiting, Poona etc.

A small water-power plant has been put up not far from Satara, the historical Seat of the Bhonslas of Maharashtra (see H. E. I. I. p. 287). This will supply power at 400 volts and energy for domestic appliances at 230 volts to the city and its few industries. The two 60kW alternators generate 3300 volts. The Voith turbine will work

at 538ft. head. Particulars of this installation will be found in

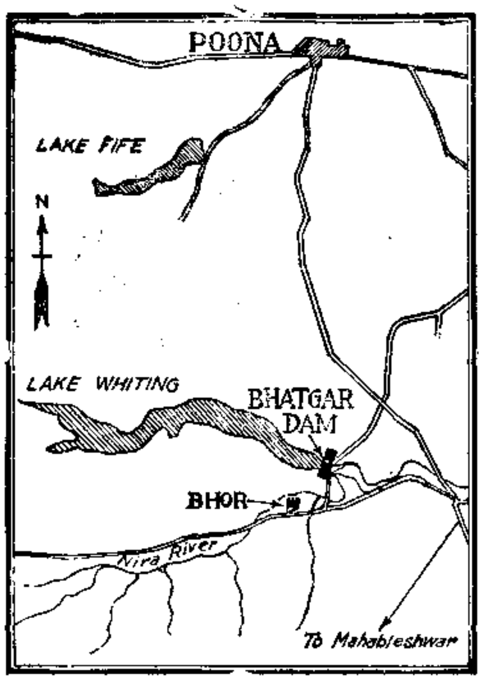


Fig. 17. Lake Whiting,
Bhatghar Dam.

Appendix I. Fig. 18 shows the Satara Power House. The Satara scheme is a combined water-power and water-works scheme. The headworks consist of an earthen dam across the Urmodi river and a storage reservoir created thereby known as the Kas Tank, which is about 18 miles from Satara. The average rainfall is in the neighbourhood of 80 inches. Water from the Kas Tank is conveyed in an open canal and at places in iron pipes or troughs. There is a fall of about 200 feet in 3 miles The canal ends at the filter near Yeoteshwar temple. From here the water is carried in a masonry duct to the grid-chamber where it enters a 12"C. I. main which goes 4,000ft. to the settling tank, made of reinforced cement concrete. From the settling tank, a 9" pipe is laid for a distance of 3,750ft. upto the Forebay at the peak-end. The Forebay has a capacity of 100,000 gallons and its full supply level is 3,239ft. From the forebay, a 9"–dia. penstock leads the water to the Power House, where the shaft-level is 2,701ft., giving a gross head of 538 feet. The net head is

about 480ft.; the corresponding pressure being 210lbs. per sq. inch. The water available for power purpose is about $1\frac{3}{4}$ cusecs. Two impulse turbines of about 75 b. h. p. each direct-coupled to a 60kVA 3,300-volt alternator are at present installed. The switchboard is of the steel cubicle type and was supplied alongwith the alternators by Messers. Siemens. The tail-water is chlorinated and then taken to the Municiple Pure-water tank for distribution to the city. The voltage at the city substation is 3,150 volts. Distribution is 3-phase 4-wire, 230V for lighting and 400V for motors. The electrical works cost about Rs. $1\frac{1}{4}$ lakhs and bring in an annual income of about Rs. 2,000. This information has been kindly furnished by the Chief Engineer of the Company, Mr. G. M. Marathe.

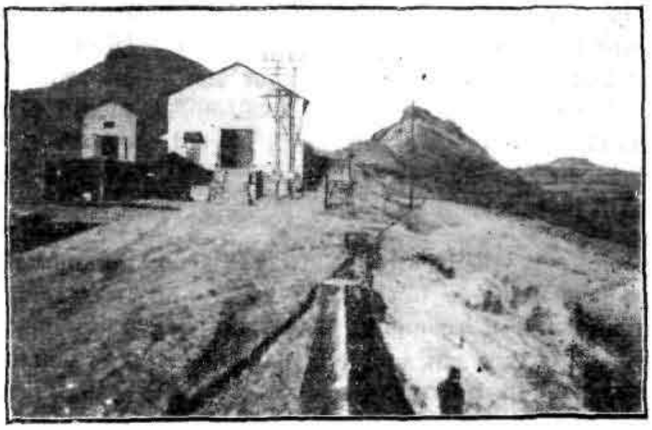


Fig. 18. Power House,
SATARA.

A 45,000 h. p. hydro-electric installation with reservoir created by a 75ft. high dam across the Bhagavati river was to be undertaken in Kolhapur State at Radhanagri Lake not far from Panhala fort and about 35 miles from Kolhapur to give electricity supply not only for the needs of the big towns of this premier Southern Maratha State but also for the purpose of mining of bauxite or laterite and the preparation therefrom of aluminium at Phonda below the Ghats where the plant will be located, the head being 1300ft., and perhaps also the manufacture of other articles or metals within the territories of the Maharaja Chhatrapati of Kolhapur who is the direct descendant of the great Shivaji. The State is likely to be connected by railway to the Konkan or coastal region of Bombay Presidency, by the time the project is begun and before it is completed, particularly if the works are on a large scale.

The magnificent Koyna river scheme of Southern Mahratta Country which was expected to provide 300,000 h. p. for preparing electro-chemical products including aluminium has remained in cold storage since 1918 though considered feasible by famous engineers (H. E. I. I. pages 93 and 94). The *Times of India* for June 28, 1934 gives the following information about the latest hydro-electric project of Western India. " In Kolhapur, the situation is unique in as much as the bauxite can be quarried, conveyed by rope-way down the hill to the Alumina works and again the alumina can be carried by a ropeway down the Ghats to the reduction works where the foundry and roller mill will also be located. This will give to this enterprise a consolidated situation and economy of working such as is not existent in any other country. It is well-known that there are other important deposits of bauxite or laterite in India but none of them are so situated as to make economic utilisation possible. The latest hydro-electric develeopment for aluminium production cost £60/- per kilowatt. The Kolhapur development should not exceed £34/-. As the bauxite is of an average quality much superior to that used in France and Great Britain, the amount of chemicals required will be considerably less.

A special port will be arranged so that incoming materials and outgoing products will be in the main water-borne and this will be no little measure of economy. There are heavy tariffs against imported metal of this sort and this advantage alone should prove sufficient to make the enterprise a success.

The hydro-electric development will be carried out much along the lines of those of the Andhra Valley Power and the Tata Power Co. The catchment area is sufficient to ensure a regular run-off of rainfall more than sufficient to satisfy the requirements of the contemplated metal production. The development is planned to be carried out in two stages; the first stage will have a capacity for the production of 5000 Tons of metal per annum and the second stage, at a fractional comparative cost of the first, will have an added capacity for the production of 4000 tons, making a total of 9000 tons per year. When full, the storage reservoir will have a superficial area of about 7sq. miles. The average effective head will be 1120 feet and the available quantity of water will be 300 cubic feet per second in continuous service which will produce 24000 kilowatts of electrical power".

" Generating plant for the processes will consist of five Pelton type water wheels each of 9000 h. p. driving in tandem two direct-current generators working in parallel as a unit at 260 volts, delive-

ring 24000 amperes to a set of reduction furnaces. There will be ultimately four such groups of furnaces, and one water wheel with its double generator unit will be held in reserve as spare. The unique grouping of high-grade bauxite and cheap electrical energy assures the possibility of cheaper production than obtains elsewhere.

Actually the amount of aluminium brought into India in any one year has been about 8000 tons. The market condition has been investigated and it is believed that with proper sales propaganda which hitherto has not been in evidence, the market can be revived to equal this amount and to exceed it. If however at the outset, the entire output is not saleable in India, there is nothing to stand in the way of export; in fact owing to reduced cost of production the Company must even so have an advantage.

In addition to the continuous current generating plant which is to be devoted entirely to aluminium production, an alternating current plant is also contemplated which will be so placed as to utilise again the water discharged from the water weeels of the main power house.

A good deal of money has been expended in connection with this contemplated project and it has been proven from every point of view. The capital amounting to £ 1,500,000/- is being privately subscribed, and the company is to be registered and formed without a call being made on the general public". As was anticipated, the company formation did take place during the month of July 1934, but work has not progressed as was expected.

In the waters of the Dudh Sagar (meaning Ocean of milk) waterfall which is situated not far from the frontier of Bombay Presidency and Portuguese Goa, the Government possesses a potential source of power that can without much difficulty be developed and transmitted to the principal ports and towns round about Goa on the Western coast of India and not far from Londa on the M. & S. M. Ry. The Marmugao Harbour Electric Scheme is already in hand.

Penstocks have been provided at the base of the Bhandardara Dam across the Pravara R. for turbines calculated to give 4570 h p. as the Dam is to be 270 ft. high but no power equipment has been installed as yet. The hydro-electric project of the Sankheda Taluka of Baroda State has not been taken in hand, as it was considered unlikely to make it a success financially. It is possible that the Nerbada river may be harnessed at a suitable spot in Gujarat to run cotton mills and gins and other works, but the project has yet to be seriously studied, though Ahmedabad has a good load ready for it.

According to a report published in the *Times of India* for April 11, 1935, Dr. M. S. Patel of the Department of Industries, Bombay has discovered a high-quality bauxite hill in the Bassein Taluka of Thana district, within 30 miles North of Bombay city and about 3 miles from a navigable creek which meets the Arabian Sea near the island of Arnala. "There should be no difficulty in operating successfully a 3000-ton plant per year, requiring 75 million units of electrical energy. This energy is avilable from the Tata Power units as one of them is working only to half its capacity". "The estimated cost is about 50 lakhs to give a profit of about 30 per cent on the cost of production" (Nov. 1936). It is reported that to supply the town of Dhari, Amreli District, Baroda State, the 30-foot Waterfall (Khodiar) is to be harnessed and utilised to generate electrical energy.

Anent Tata Hydro companies (see Chapter VI), Mr. T. G. Mackenzie has published the following information, *vide The Times of India*, Jan. 22, 1937 :—

"(1) 0.55 anna per unit was not a rate for supply of electrical energy, but a rate which also included rental of transformers and electric motors; (2) the rate for electric supply was not increased during the Great War when the price of coal soared. The truth is that the Andhra Valley Co. went into operation only in 1922 and then put into effect a rate higher than that being charged by the older Hydro Co., because of the high cost of machinery and supplies incidental to the construction of its plant during the war and post-war period; (3) the rate of Rs. 50/-per annum per kilowatt of maximum demand plus 0.425 anna per unit consumed was never at any time applied to industrial loads.

Taking 100 as representing the index cost of power purchased by Bombay industries during 1927-28, the average cost per unit for that and subsequent years was as follows :—

Year	Index	Remarks
1927-28	100.0	N. B. The slight increase in 1933-34 was due to curtailed operation resulting from strikes in the textile mills.
1928-29	100.0	
1929-30	96.6	
1930-31	94.2	
1931-32	91.7	
1932-33	90.0	
1933-34	92.1	
1934-35	77.5	
1935-36	67.4	
1936-37 (6 months)	65.6	

The price of coal in Bombay has (just) risen (see announcement in *The Times of India*) from Rs. 14/- per ton to Rs. 16/- per ton, but the Hydro companies are not on that account withdrawing the concessional rates granted voluntarily to mills and industries within the life of their existing agreements for power supply".

Reference has been made to the possibility of putting up a power station at the base of the 260 ft. high Bhandardara Dam. This dam is across the Pravara river, a tributary of the Godavari, and is located in the Ahmednagar District of the Bombay Presidency, 22 miles from Ghoti Railway Station of the G. I. P. Railway. About 5 miles below this dam, the water passes over falls at Randha. One power station could be put up at Bhandardara and another a few furlongs below Randha Falls. The head at the former place would be about 180 feet and at the latter 110 to 160 feet. With 300 cusecs of water, the former could supply 3,600 kW and the latter 2,200 to 3,200 kW, i. e. nearly 6,000 to 7,000 kW continuously, altogether. For guaranteeing constant supply of water to the latter station, a compensating storage tank would have to be constructed by damming the river Adala, a tributary of the Pravara, at a cost of about Rs. 120 lakhs (T. R. W. P. R. page 84). If the Bhandardara Dam were raised to 270 feet, the compensatory storage could be reduced and a balancing tank may be built at another place, necessitating a quarter to a third of the figure mentioned in T. R. W. P. R.* With the present trend towards better finances, the Government should be able to take in hand the harnessing of Pravara at these two places, particularly as market for power exists and is likely to be forthcoming. Belapur, 60 miles away, has two sugar companies and Deolali-Nasik load is about 25 miles away. Besides these, Igatpuri, where the G. I. P. Ry. electric locomotives at present terminate and which can take a good amount of power if electrification of the railway beyond Igatpuri is begun, is only 32 miles away. Ahmednagar is 70 miles away and could also be supplied with high-tension energy if the demand justified. Nasik-Deolali Company is likely to scrap its oil-electric plant in favour of cheaper energy from Pravara, judging from the fact that Poona did so before in similar circumstances. The present Nasik plant was once installed in the Poona City Power House.

* T. R. W. P. R. = Triennial Report on Water Power Resources, 1922.

CHAPTER IX

MUSSOORIE WATER POWER PLANTS.

Facts and figures have been given at length concerning the Mussoorie Water Power Plants in the book on "*Hydro-electric Installations of India.*" Further facts and figures culled from the Report of the Superintending Engineer, Public Health Department, U. P. and from an article in the "*Distribution of Electricity*" for *Jan. 1933* are given below:—

TABLE No. 20.

Mussoorie Plants, Equipment Installed.

A. (Extract from "*Distribution of Electricity,*" Jan. 1933).

I. *Original Plant (1909).*

(a) Hydro-electric Station at Bhatta R. consisting of three 150-kW 6600 volt alternators.

(b) Two steel power pipe-lines, 16" to 12" diameter, 1000 ft. head, length 4500 feet.

(c) One pumping station for delivering 1100 gallons per hour.

(d) Twelve sub-stations, 6300 volts to 380/220 volts.

II. *Present Plant (1932).*

(a) Hydro-electric Station, two 500kW. sets and two 1000kW. sets.**

(b) Three steel pipe-lines.

(c) Peak-load Diesel Station, 3 sets of 320kW.

(d) Four pumping stations, delivering 31,200 gallons per hour.

(e) Thirty-seven Substations.

N. B. The whole undertaking is financed by the Government of the United Provinces.

** After the installation of the 1000 kilowatts sets which generate at 400 volts, which is stepped up to 6600 volts through transformers, no trouble was experienced from thunderstorms. Before this, 'burn-outs' were frequent.

In 1929 the Diesel Station at Dehra Dun was erected as the demand exceeded the capacity of the Hydro-electric Station during the dry weather.

III. Revenue and Expenditure, 1931–32.

Capital Value (Unpaid Balance of Govt. Loans)	Rs. 19,66,454
Sales of electricity, meter rent, etc.	3,46,858
Water receipts	97,047
	4,43,905
Annual Expenditure on Establishment and Maintenance	1,91,210
Annual Repayment of Govt. Loan (Interest and Sinking Fund)	2,24,486
	4,15,696

Annual Value of Services rendered by the Electrical Dept. to the Municipality :—

Road Lighting	24,000
Lighting of Public Buildings and Municipal Staff Quarters	10,000
Water Working Pumping	98,000
	1,32,000
Units Generated 1931–32	3,555,921
Cost per unit generated (Hydro)	0.5 anna
„ „ „ (Diesel)	1 anna

TABLE No. 21.

Mussoorie Plants, Load Particulars.

B. Extract from the Report of Superintending Engineer. The figures are for the year 1932-33.

For Hydro Sets.

Peak Load for the year, kilowatts	785
Total kilowatts connected	4,280
„ units generated	3,458,685
„ cu ft. of water used	207,485,100
„ hours of running of 3 units	8,978
„ units sold and receipted	2,948,988
„ revenue	Rs. 4,25,408
„ charges	„ 3,75,288

For Diesel Sets

Peak lead for the year, kilowatts	516
Total units generated	214,387
„ hours	1,420

The following extract from Garckes '*Manual of Electrical Undertakings, 1933–34* refers to the Mussoorie-Dehradun Hydro-electric Scheme :—

Primarily to supply Mussoorie with water and light the public roads, secondarily to supply Mussoorie, Dehra, Landour, etc. with energy for private lighting, etc. Supply first given to Mussoorie on 25–5–1909 and to Dehra 15–11–1914.

System. 3-phase 50–cycle 6600 volts ; 27 substations giving 380 V for power and 220 V for lighting; 4-wire distribution. Overhead mains to Dehra 22 miles.

Plant. Water collected at confluence of the Bhatta and Kiarkuli streams. Gross head 1000 ft.; length of pipe-line 4350 ft. Two Siemens Gordon 625 kVA sets; two Boving-Metvick 1250 kVA sets at Hydro-electric Power Station and three 400 kVA Sulzer–BTH Diesel sets at Dehra Dun. Total capacity 4950 kVA.

Supply statistics. Price charged per unit; lighting 6 annas, power 1 anna, fans 6 annas. No. of consumers 2300. Public Lighting 100 kW.

Total connections 4250 kW. Units generated 3,500,000. Maximum Load 860 kW. Load factor 35 p. c.

Fig. No. 19, a lay-out corresponding to that of the Mussoorie Hydro-electric development, may be seen in H. E. I. I. Fig. 59.

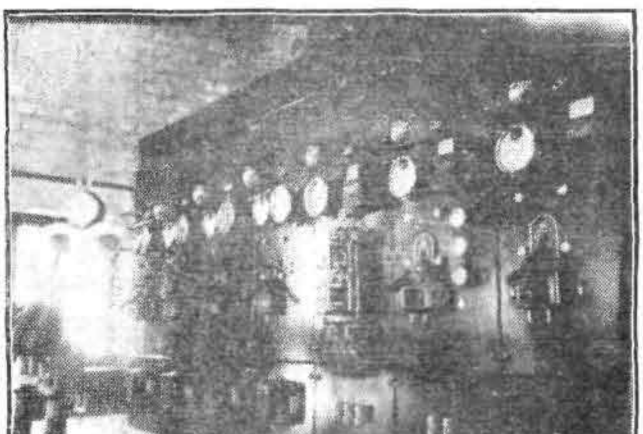


Fig. 20. Durgapur Power House : Switch Board.
NAINI TAL.

CHAPTER X.

NAINITAL LAKE WATER POWER PLANT.

The source of water for this plant is the large lake after which the summer seat of the Government of U. P. is named NainiTal, the word Tal meaning a large tank or lake and Naini being the name of the goddess of the Hill Station, with a temple dedicated to it located at one corner of the Tal. The works associated with the plant were designed by Mr. G. McC. Hoey in 1919, started in 1920 and finished in 1922–23. Supply commenced on 8–8–22. The design provided not only for a hydro–electric installation but also for works for water supply to NainiTal; the latter were completed in 1923–24. The total cost rose to a little over 20 lakhs owing to unexpected increase in prices and fall in the sterling equivalent of the rupee. For facts and figures which follow I am indebted to the Reports of the Superintending Engineer, Public Health Dept. U. P. and to Mr. R. L. Khanna, Resident Engineer, Durgapur; the latter kindly supplied photographs, one of which is here reproduced.

From the lake, the water is led into a Cast-Iron Pipe, 20in. in diameter, through a screening chamber divided into two parts and provided with a scouring pipe of the same diameter. From each half of the chamber issues an Air Vent and a 10in. diameter pipe, the latter made up as follows:-Cast iron, 2,900 ft.; welded steel $\frac{1}{4}''$ thick, 2713 ft.; 5/16in. thick welded steel, 1072 ft. These pipes terminate at the Power House at Durgapur. From either of them water can be admitted to the water wheels, or escaped to the Tailrace channel, according to the needs of the moment. Near Krishnapur, half way to the P. H., there is an Air Vent. Expansion joints and anchor blocks have been provided as and when necessary along the Pipe-line for both the Pipes. At the power house, there is a 30–ton Anchor Block and from each penstock issues a branch, the two branches joining and feeding a set through one intake pipe. Other sets are similarly fed by water from either penstock, the quantity of water is measured by a Lea Recorder and varies naturally according to the requirements of the demand on the Station, rising to a maximum of 75,000 gallons per hour and falling to less than one half or one third as much at ordinary times. The head of water is about 1,500 ft. (423·7 meters), 650 lbs. per sq. in.

Four generating sets exist, one of them being fitted with a fly-wheel and being of 350 kilowatts capacity. It consists of a Swedish Boving 520 h. p. Turbine coupled to a Metro-Vick 439 kVA alternator of the following rating :—439 kVA, 0.8 p. f., 3-phase, 50 cycles per second, 3500 volts 1,000 r. p. m., 72 amps. per terminal. Three Pelton Wheels, each of 30 in. mean diameter, designed to develop 220 h. p. on 1395 ft. head, using 110 cu. ft. of water per minute are direct-coupled to three-phase alternators rated as follows :—188 kVA, 150 kW, 3300 /3500 volts, 31 amps, 1000 r. p. m., 50 cycles per second. These are Gilkes-Mather Platt combinations. The nozzle is 1 in. in diameter and the pressure for the governor is 50 lbs. per sq. in. The maximum demand at Divali time recently was 450 kilowatts. This was surpassed by the demand during the Jubilee celebrations of May 1935. Formerly the peak load was 365 kilowatts. The spare plant is for extensions which were contemplated. A small transformer supplies power needed at and near the Power Station.

Each exciter is rated at 25 V, 60 A, 1000 r. p. m., but the voltage and current vary slightly during use. The Messrs. Mather Platt sets were installed in 1922 and the Boving set in 1929. The power factor for pumping and power load is about 0.77 and that for lighting and domestic load 0.93. One way of improving the power factor is to instal a synchronous motor and run it as a condenser by over-exciting its field. As the NainiTal Power House contains spare synchronous machines which are not required to be run as generators as originally intended, it would be desirable to disconnect them from the prime movers and operate them as motors, if the manufacturers guarantee that when worked in the inverse way, it would be possible to obtain leading current from them as from synchronous condensers. Another way to utilise the spare power available is to erect funicular railways in the hills round about NainiTal and operate them electrically as in Switzerland. Nearby places to which power could be transmitted are :—Bhowali 6 miles, Kathgodam 12 miles, Haldwani 15 miles, Ranikhet 27 miles, and Almorah 32 miles. By taking the lines as the crow flies, it would be possible to minimise the cost considerably in some cases. The main switchboard in the Power House consists of 8 panels, on one of which an Automatic Voltage regulator is mounted. For facility of lifting and shifting machinery inside the Station, a 5-ton crane has been fitted up in it. Fig. 20 shows the NainiTal switchboard inside the Durgapur Power House. The automatic voltage regulator can be discerned on the central panel.

Three power conductors and one ground wire over them, comprising one H. T. Line, supply power to the NainiTal Receiving

Station, 2.2 miles away. Another line of smaller calibre runs from the Power Station to a substation, near the Govt. Vaccine Depot at Patwa-Dangar, one mile away. The NainiTal Line conductors are No. 3 or 4 in size, the L T. conductors varying from No. 0000 to 10. The ground wire and the street lighting wires are also No. 10. At the 3 or 4 substations to which 3300-volt feeders go, transformers reduce the voltage to 380 volts three phase and 220 volts for lights. The following figures for the year ended Mar. 31, 1933 would interest the reader :—total kilowatts 1730, average quantity of water per unit generated 35.8 cu. ft., total hours of running for all the sets working 8747, units generated 11 lakhs; units sold, 7 lakhs; revenue one lakh 69 thousand rupees and total charges one lakh and 53 thousand, including interest, sinking fund and maintenance. In May 1936, about 690,000 gallons of water were used during 24 hours. There are *4 pumping sets; two high Zone and two Low Zone; the former* 75 H. P., 48 H. P. and the latter 30 H. P. per pump.

The following figures have been furnished to the Author through the courtesy of the Municipal Secretary, NainiTal :—

TABLE NO. 22.

NainiTal Supply Statistics.

Total number of connections				1872
„ kilowatts installed				1811
„ „	„	lighting		410
„ horse-power	„	industrial		14.5
„ „	„	pumping		371
„ kilowatts	„	street lighting		36
„ number of	„	lights		730 summer
„ „	„	„		474 winter
Rate per unit, for lighting			0-8-0 less 25 p. c. discount	
„ „ „ „ pumping			0-3-0 annas	
„ „ „ „ heating			0-1-4 anna	
Income from electric energy		162027-0-0 rupees		
Maintenance expenditure including loan repayment		162407-0-0		

Other figures for the NainiTal Supply :—

Motive Power, less than 250 units per month	0–2–8 per unit
„ „ more „ „ „ „ „	0–1–4 „ „
Meter rent, single phase	0–8–0
„ „ Two „	1–0–0
„ „ Three „	1–8–0
„ Testing fee	5–0–0
If consumption not on record, charge per month	1–0–0 per point.
If lamps not connected to mains through meter, 16 to 32 c. p. m. f. lamps	2–0–0 per month
50 c. p. m. f. „	3–0–0 „ „
100 „ „ „	5–0–0 „ „

provided payment is made before the 10th, of the month.

If not paid before 10th., the charges would be 2–8–0, 3–12–0 and 6–14–0 respectively.

Security may be demanded at the rate of Rs. 2/– per lamp and Rs. 10/– per power point installed as a deposit, to be credited in the final bill for the year if bills are regularly paid during the year. Otherwise the deposit will be forfeited. If the current is exceeded, supply will be cut off.

The load factor for the Station would be much higher if the plant installed were more fully utilised. An extension equivalent to the present average load on the station could be easily met without requisitioning extra generating plant and this extra load would be forthcoming by extending the Area of Supply to places within 30 miles of the Durgapur Power Station. It was hoped that the financial difficulties in the way of this extension would be surmounted, as the Chief Engineer for Irrigation and Hydel was Sir W. L. Stampe who carried through the Ganges Canal Power Scheme. The Municipal Improvement Committee has recommended that more numerous and more powerful bulbs should be used for street lighting.

CHAPTER XI.

UPPER GANGES CANAL POWER PLANTS.

Remarkable progress in the development of hydro-electric power latent in the falls that occur at intervals along the Ganges Canal has been made in recent years. The original Bahadrabad Installation was put up over 20 years ago to supply power required for the construction of the works at Bhimgoda near Hardwar, the head-works of the Upper Ganges Canal, vide pages 168 and 169 of *Hydro-Electric Installations of India*, but it was not till 1929 that the present enlarged installation was constructed right across the Canal in contrast with the old Bahadrabad and the present Sumera installations, both built on separate foundations on by-pass channels. The Report of the new scheme was issued early in the year 1931. Two falls, half a mile apart, have been merged into one of about 20 ft., for the new Bahadrabad Station which was opened for service in March 1931. The plant installed in it is as follows :—

Four sets of vertical turbo-alternators, working at 17 ft. average 'head' and 187 r. p. m., each consisting of a 1000 h. p. (one Kaplan or propeller type, 3 Boving or Escher Wyss) turbine with 4 blades, each 3 ft. long, a fly-wheel and a 3-phase alternator rated at 750 kVA or 600 kW at 0.8 power factor, 6600 volts, 50 cycles per second, were originally installed. Recently, two more sets of 1000 kW each have been added. The output of the station is thus 4400 kW at 0.8 p. f. One more set of 1000 kW could be installed. The top bearing of the set takes the whole weight and water thrust. The minimum available water is 4000 cusecs. The gates provided in the turbine channel are automatic in action, to maintain the upstream water-level irrespective of variations in level of water in the canal and to ensure continuous and steady supply for irrigation. The governor is worked by oil under a pressure of about 200 lb. per sq. inch. The exciter is a 14 kW 150 volt 93 amperes, direct-current shunt-wound generator. Tirrill Regulators for automatic regulation of the voltage of the a. c. busbars, and over-load relays and earth-leakage relays have been installed for ensuring steady pressure of, and for protection of, the electrical plant.

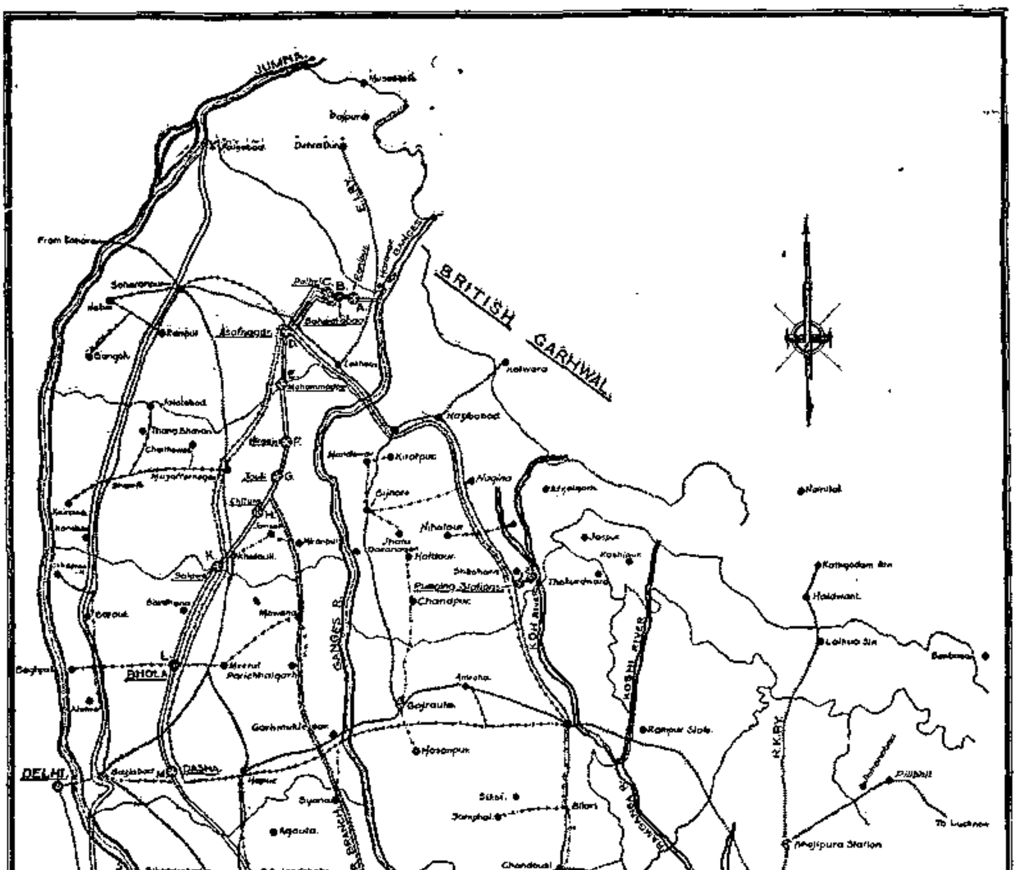


Fig. 21. Water Power Plants and Lines,
UPPER GANGES CANAL.

The L. T. voltage is stepped up from 6600 volts to 37.5 Kilovolts by two sets of three single-phase outdoor transformers, each connected as a 3–phase bank. Double-circuit H. T. lines go out from Bahadrabad. The higher pressure, 37,500 volts, is for distant places. The lines are tapped for supply of power to rural areas and small towns where the voltage is lowered to 400 volts for motors and 230 volts for lights. Roorkee has two substations for this purpose to get the secondary voltage of 400 volts, one for the Engineering College and the other for the City. The step-down transformers are in some places placed in fenced areas out of doors, or even mounted on poles. The total length of the transmitting lines of the whole U. P. Grid is 2000 miles approximately. Other generating stations which feed the 'Grid' have been constructed lower down on the same canal where falls suitable for hydro–electric development exist, namely at Bhola near Meerut, Palra near Khurja and Bulandshahr and Sumera near Aligarh and Agra. Palra is at mile 148 and Sumera at 163 mile of the canal. The Bhola and Palra plants were sanctioned in 1929 and commenced supply in 1930. There are four 500 h. p. and two 800 h. p. sets at the former and three 300 h. p., sets at the latter place. Arrangements have been made to render unnecessary the closure of the canal for repairs to bridges and falls by diverting at times of lowest demand the minimum-power water supply through certain bays of the falls and bridges in rotation. The Sumera generator capacity is 600 kW or 1000 h. p.; there are 2 such sets working there at a head of 15 to 19 ft. The 'head' utilised at the Bhola station is 12 to 14 feet and at Palra 8 to 10 ft. only. The minimum water available is 1700 cusecs at Bhola, 1200 at Palra and 1000 at Sumera. For the present 8,500 h. p. is always available but ultimately, it is hoped, 35,000 h. p. will be developed and 2000 h. p. provided by oil-engine generating sets. The scheme will enable 66 towns to be electrified and will cover an area of over 10,000 sq. miles. The U. P. Government estimate a profit of 1.45 lakh in 1935–36 and 3¼ lakhs in 1940-41, judging from the increase in the demand for electric power. The cost of the plants is comparatively high because of the low 'head' but the volume of the water is large and the flow varies from 5000 to 8000 cusecs at the canal head works. The 'Grid' networks cover a fertile region where demand for power will be great, thus making the Scheme a success after a few years. The lines from Bahadrabad and Bhola stations work at a pressure of 37,500 volts but the Palra transformers raise the pressure from 400 to 11000 volts only. Bahadrabad is between Hardwar and Roorkee, about 9 miles from the former and 12 miles from the latter city. Bhola is at mile 84 of the canal, say about 90 miles from Hardwar. The Bahadrabad and Bhola plants as indeed all

'hydel' plants are tied together electrically, to supply each other's load. The 375 kW Bhola Station alternators are rated at 470 kVA, 400 volts, 187.5 r.p.m., 50 cycles, and have 32 field poles each, the field current being 80 amperes and voltage 95 to 100 volts. The Sumera transformers will raise the voltage from 6600 to 11000 or 37500 volts. At the substations for distribution, no matter where located, the standard low-tension voltages are 400 volts for power and 230 volts for illumination. The principal transforming stations are spaced about 12 miles apart. Electric power will be used on a large scale for pumping water from rivers or canals at low levels to irrigate areas not reached by canal water flowing under the action of gravity. The U. P. Government will make electric supply available even in out-of-the-way places at only one anna or $1\frac{1}{2}$ anna per unit, to popularise the use of electric power. Acknowledgments are hereby made to the Engineers and Publications of 'Hydel' branch of U. P., P. W. D., particularly Mr. now Sir W. L. Stampe, a colleague of the Author when he was Professor at the T. C. E. College, Roorkee. Figs. 22, 23, 24 and 21 show respectively the forebay side at Bhola, the power house downstream side at Bhola, the power house machine room at Palra and the map of the Ganges canal Hydro-electric supply region.

Ths following description culled from a Government pamphlet will give the reader an idea of rural electrification. A branch line has been taken off the Bhola-Meerut Line. It operates at 11,000 volts, has a total length of 9 miles and cost Rs. 33,982. Three consumers at first guaranteed a return of not less than $7\frac{1}{2}$ per cent on the capital outlay of their respective lengths of line. They have (a) 25 h. p. transformer, (b) 10 h. p. transformer and (c) 60 h. p. transformer respectively. After the branch line was constructed, ten more applications were made to the Irrigation Department, of the activities of which the Hydro-electric scheme is a part. The electric power is used for the following, among other, appliances :—

(a) Lime disintegrator, 3" *tube-well*. A bone factory and additional tube-wells are to be installed. (b) 4" tube-well, 6" tube-well for sugar-cane irrigation, cane crusher. (c) 4" tube-well (d) 5" tube-well (e) 3" tube-well. It will thus be seen that *tube-wells* are increasing in number. This is all to the good, as it will relieve water-logging by diminishing the sub-soil water which is responsible in some places for efflloresence and salt in the soil making it difficult to cultivate it as successfully as before.

For bulk supply of power 9 pies per h. p. hour is charged. The hire of a meter is Re. 1/- per month. Retail rates for electric energy

are as follows :—For lights and fans, 0–5–6 per unit ; for industrial motors, 0–1–6 ; for agricultural purposes and irrigation pumping, 0–1–0 per unit. Specially low rates are quoted for industrial motors working long hours.

The Legislative Council has made a grant of 2 lakhs for the construction of additional branch lines, which are usually ready within 4 months of the date of the receipt of the guarantee-deposit from prospective consumers.

TABLE NO. 23.

'Hydel' Load and Units sold.

Units sold for (Industrial power) 1st. 10 months	of 1932–33—	3729373
" " " " " "	Domestic	3445408
" " " " " "	of 1931–32—	2056559
" " " " " "	Domestic	2147978
Connected Load (Industrial and domestic)	March 1933—	6018 h.p.
" " " " " "	1932—	3748 "
" " " " " "	1931—	1394 "

Two instances of 'water-power' working to promote 'irrigation' may be cited.

The Ramganga pumping scheme will utilise 2400 kW. Hydro-Electric with 500 kW. Oil-Engines reserve, to lift 200 cusecs to a height of 35 ft. and in order to irrigate 50,000 acres of dry tracts of Moradabad district. Similarly, Sumera will supply power to pump 110 cusecs from the Kali Nadi to a height of 13 ft. and by means of weir and duct to increase the depleted water supply in the Ganges Canal, the parent (water) being helped thus when it is declining by its offspring (electricity)—an act of kindness corresponding to that of blood-transfusion among human beings. As demand for power increases additional falls, of which there are nine yet unharnessed, will be able to supplement the output of the existing plants and bring the total to 20,000 kW approximately. Four commercial companies have undertaken the actual distribution of hydro-electric power so far available, thus combining private enterprise with State initiative. Each company has guaranteed a minimum sum to be paid to Government as revenue, depending upon the extent of distribution and inten-

sity of load within its area. One of the companies has guaranteed about 2 lakhs, the second Rs. 1½ lakhs approximately, the third a little over a lakh and the fourth Rs. 39,050 only.

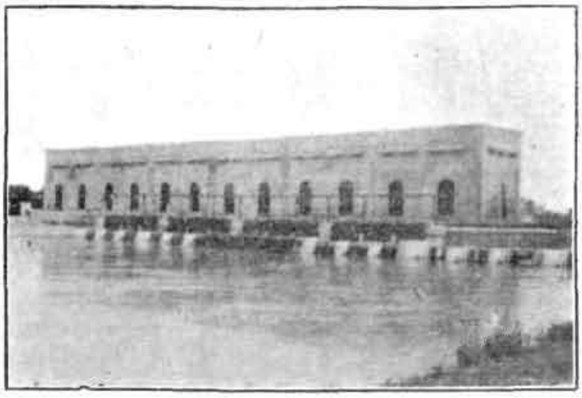


Fig. 22. Forebay Side, Power House, BHOLA FALLS.

The U. P. Government have a 5-year plan to sink tube-wells in the Western districts of Meerut, Muzaffarnagar, Bijnor and Moradabad for which Rs. 60 lakhs has been sanctioned. It costs Rs. 5000/- to complete one 1½ cusec tube-well. The five years will finish in 1937-38.

The following is the list of the stations, large and small, associated with the Ganges Canal Hyadro-Electric Grid, from which it is clear that the net is spread far and wide; Shahdara for instance being close to Delhi, outside the U. P.:—Jwalapur, Gurukul, Tibri, Kankhal, Mayapur, Laljiwala.

Bahadrabad, Dhanauri, Pirankaliar, Roorkee (City, E. I. R., College), Lhaksar, Balawali, Najibabad, Najibabad E. I. R., Nagina, Dhampur, Sherkot, Nehtor, Seohara, R. G. Pumping Stations No. 1 and No. 2, Sahaspur, Kanth, Moradabad (City, Civil Lines, E. I. R.), Manglore, Purqazi, Muzaffarnagar (City, Civil Lines), Khatauli, Jansath, Miranpur, Deoband, Sardhana, Charthawal, Thanabhawan, Shamli, Kiaran, Kandhala. Chhaparauli, Baraut, Baghpat, Khekra, Saharanpur (City, N. W. R.) Gangoh, Rampur.

Bhola, Meerut Nos. 1, 2 and 3, M. E. S. Meerut, Mawana, Parichhatgarh, Moradnagar, Ghaziabad, Shahdara, Pilkhua, Faridnagar, Hapur, Garhmuktesar, Garhmuktesar (E. I. R.), Syana, Amroha, Sambhal Hatim Sarai No. 1, Chaudhry Sarai No. 2, Hiatnagar No. 3,

Sambhal Tarin Sarai No. 4, Bilari, Chandausi (City, E. I. R.), Bijnor, Mandawar, Kiratpur, Jhalu, Haldaur, Chandpur, Bachhraon, Hasanpur, Jehangirabad, Shikalpur, Khurja, Gulaothi, Bulandshahr, Sikandrabad, Dankaur.

Palra.

Sumera.—Kalinadi Pumping Station, Dibai, Anupshahr, Harduaganj, Aligarh (City, E. I. R., University Nos. 1 and 2), Hathras No. 1, Mursan Gate; (No. 2 Qila Gate), Dayalbagh, Tundla, Simbhaoli, Rahimpura, Landhaura Estate.

Saharanpur-Gangoh, Strawboard factory,

Moradabad–Chandausi, Raja-ka-Sahaspur, Chitendra Singh's farm, Kandarki, Roza Nagalia, Mundia.

Bilari–Sambhal, Hazratnagar Garhi.

Bijnor–Gajraula, Inampura, Ismailpur, Abdul Salam's well.

Bijnor–Mandawar, Raja Jwala Prasad's farm. R. S. Jain Bros. farm.

Nagina–Bijnor, Agricultural farm Nagina, Sarai Dadumar,

Dhampur–Sherkot, Sherkot Estate.

Dhampur–Nehtor, Ch. Manoo Singh's farm. *Shamli–Loop,* Bagra.

Khatanli–Miranpur, A. Khan's farm. Sikandarpur. Akramkhan's farm.

Bhola–Meerut, Farms of W. Din, M. Singh, M. Lal, C. Singh, M. Saidi, Mil. Grass, Gor Jat Lime factory, P. Prasad's well.

Meerut–Mawana; Bachola. *Bhola–Baghpat. Dasna–Ghaziabad,* Ingraham Institute, H. Das farm. *Ghaziabad–Shahdara* wells, of Burgess, Waugh, Budha Mali. *Bulandshahr–Sikandrabad,* Kanarsi, Walipura, S. Lal factory, Agric. School. *Palra–Khurja.*

Palra–Jehangirabad, Halpura, Rajpura Chandok, Dhalna, Barauli, *Sumera 11 kV Lines.* Talibnagar, Chhatari, Pindrawal, Atrauli, Asgharabad, Gabhana, Birpura, A. Khan well, Keventer farm, Gabhana Gin factory.

TABLE NO. 24.

Ganges Canal Power Lines.

Voltage (kilo-volts)	Circuits	Distance (miles)	Supports	Route.
66	Single	79	Towers	Bhola-Sumera.
37.5	Double	178	90 lb. rails	Bahadrabad to Roorkee, Asafnagar to Seohara. Roorkee to Bhola.
"	Single	134	Poles	Roorkee to Saharanpur, Seohara to Moradabad, Bhola to Dasna. Dasna to Garhmuktesar, Hapur to Bulandshahr and Palra.
"	"	202	90 lb. rails	Garhmuktesar, Moradabad, Amroha; Sumera, Harduaganj, Aligarh and Hathras Kilha.
"	"	40	extension	Hathras Kilha to Dayalbagh near Agra. Dayalbagh to Tundla.
11	"	250	90 lb. rails	Nagina, Bijnor, Jhalu, Mandawa, Kiratpur, Nihataur, Sherkot, Meerut to Mawana and Parichhatgarh; Saharanpur, Nakur, Rampur, Gangoh; Garhmuktesar, Syana; Hasanpur Gajraula, Chandpur, Haldaur: Bulandshahr, Sikandrabad; Dankaur; Palra, Khurja, Shikarpur, Jahangirabad; Salawa, Khatauli, Jansath, Miranpur; Moradabad, Bilari, Sambhal, Chandausi.
"	"	148	Poles	Muzaffarnagar, Shamli, Charthawal, Thana Bhawan, Jalalabad, Kairana, Bhola, Meerut, Baghpat; Baraut, Chhaprauli, Khekra; Dasna, Ghaziabad, Sumera, Kali-Nadi, Atrauli, Anupshahr.

N. B.—37,500-volt line mileage, 590: 11,000-volt lines, 450 miles.

TABLE NO. 25.

Ganges Canal Power Plants.

No.	Name of Fall	Mile of Canal.	Head (feet)	Minimum Discharge.	KW. out-put min. Disch.	Present output.	Stand by plant.
1	Ranipur	5	9	4,000	2,320	nil.	
2	*Bahadrabad*	7	19	,,	4,900	4,400	$1 \times 1{,}000$
3	Pathri	10	10	,,	2,580	nil.	
4	Asafnagar	23	11	3,500	2,480	,,	
5	Mohammadpur	31	12	3,300	2,560	,,	
6	Nirgajni	42.5	12	,,	,,	,,	
7	Jauli	48	10	3,100	2,000	,,	
8	Chitaura	56	10	2,000	1,290	,,	
9	Salawa	67	12	1,900	1,472	,,	
10	*Bhola*	84	14	1,700	1,535	2,700	2×660
11	Dasna	105.6	9	1,400	813	nil.	
12	*Palra*	148.7	9	1,200	698	600	
13	*Sumera*	163.4	18	1,000	1,162	1,200	
				Total	26,370	8,900	4,200

N. B.—Out of the above-mentioned 13 falls, ten have been selected for power development. In future stations, the head will be made nearly 19 feet by raising the upstream banks.

Fig. 23. Downstream Side,
Power House,
BHOLA FALLS.

TABLE NO. 26.

Ganges Canal Scheme, Costs of Stations and Lines.

Cost per kilowatt of existing stations ...	Rs.	384-0-0
" " " " future " ...	"	325-0-0
" " Mile of double-circuit 37,500 V lines...	"	8,800-0-0
" " " " district branch 11,000 V " ...	"	3,500-0-0
" " " " farm " " " " ...	"	2,100-0-0
" " substation (30 h. p. capacity) ...	"	1,400-0-0
Cost of ultimate development (400 miles rural extension, duplication where needed, 500 State Tube-wells.) ...	"	328 lakhs.
Estimated revenue at completion in 1941 ...	"	55½ "

N. B.—The irrigation scheme will pay, if energy costs not more than 7 pies per unit.

The first stage of the scheme was completed in 1935. Early in that year, the Ganges Grid Extension Enquiry Committee came to the following conclusions :—

"(1) The scheme is fundamentally sound from an economic and technical point of view and the estimates of construction costs are reasonable on the basis of present day rates and prices.

(2) The construction of Salawa generating station (3 sets of 1500 kW), within the next 5 years, is recommended provided the load estimates are realised.

(3) Economies in the operating establishment may prove possible in the near future.

(4) The power tariffs as a whole are reasonable and sufficiently attractive.

(5) With favourable economic conditions, the load and revenue forecast for the next 5 years should be realized. An important factor in the development of load will be the progress of the State tube-well irrigation Scheme which we are satisfied is sound and consider should be encouraged."

The U. P. Government have purchased Raja Jwala Prasad's sugar factory at Bijnor for experimental purposes. "(a) Of the 135 sugar factories, 70 are in the United Provinces. There is an increasing

tendency for the large sugar factories to use hydel power for lighting and auxiliaries, while it would seem that it would be economical for the small 50-ton factory, using the vacuum process and situated away from transport facilities to use hydel power for crushing and refining. An approximate average consumption of 750,000 units with a corresponding demand of about 300 kW could be expected for every 1000 tons crushed per day in a season of 100 days. ... ...

(b) *The single-cusec tube-well* has been demonstrated to be the most suitable type. The estimated cost Rs. 5000/- is susceptible of considerable reduction. A load of 2700 kW in the 5th year is estimated." The ultimate Development is upto the year 1948-49 when the Revenue per kW—year is anticipated to be Rs. 211; for 1938-39, the figure is taken as 245 and for 1933-34 as 256. The total revenue estimated was Rs. 13·56 lakhs for 1933-34, 29·41 for 1938-39, 59·08 for 1948-49.

"The capital cost of the first stage of the scheme (completed 31-3-35) is Rs. 170,00,000 approximately. The total installed capacity under stage I is 8,900 kW and therefore the cost per kilowatt comes to Rs. 1910 approximately. The capital cost, given above, includes over 1200 miles of main and branch lines necessary to transmit energy in excess of the quantity now being developed. In other words, the transmission and transformation plant installed is sufficient to carry loads in excess of the present output. Hence the ultimate cost per kilowatt would be much less."

The above paragraphs have been quoted from the letter and the Report kindly sent to the Author by the Chief Engineer, Development, P. W. D. Irrigation, Roorkee, U. P., to whom thanks are due also for perusal of the present Chapter of this Book. The sentence below which is enclosed within inverted commas is also a quotation.

The areas suitable for State-tube-well irrigation are as follows :—

TABLE No. 27

Tube-well Areas.

Bijnor	District	...	140 sq. miles.	Ultimate development.
"	"	...	70 " "	
Moradabad	"	...	500 " "	
Bulandshahr	"	...	190 " "	
"	"	...	40 " "	
Meerut	"	...	100 " "	
"	"	...	15 " "	
Aligarh	"	...	110 " "	

The lines marked at 37·5 kV may ultimately be operated at 66 kV and the 11 Kv lines at 37·5 kV but "as lines become more heavily loaded, the installation of feeder voltage regulators might be found economically justified at certain important points and the construction of new 66 kV lines postponed."

The *Electrician* for March 27, 1936 contains the following information :—The Upper Ganges canal, which commands 4,500,000 acres passes over 13 falls, of which 8 are suitable for electrification. Of these, four were originally developed for 3 local schemes carried out in 1929–30. It was afterwards decided to link these 3 systems into a connected Grid to attain the 4 main objectives as follows :— (1) All the 88 towns in the 7 western districts having a population of 5000 and over could be electrified for domestic and industrial purposes, (2) the intervening tracts with their small towns, villages and wide-spread rural loads could be supplied with power for industrial and agricultural purposes, (3) power could be made available over a wide area for pumping water for irrigation from rivers and tube-wells and (4) connected systems could help each other at times either of maximum load or of individual failure. The 1931 project which was completed at a cost of Rs. 138 lakhs comprised 4 power stations with a capacity of 9900 kW, 800 miles of transmisson lines and 167 transformer stations. Up to date, 208 new branch lines to zemindar's farms have been constructed with a total mileage of 280 at a cost of about Rs. 6 lakhs for transmitting 3,068 h. p. A vast irrigation project has been sanctioned for the construction of some 1500 wells to command nearly 2000000 acres within the next 2 years. The Grid Enquiry Committee (1935) revised the estimate to Rs. 343 lakhs including all previous commitments. An aggregate installed generating capacity of 27900 kW will be provided, of which 20,000 kW will be available for utilisation. It is anticipated that 31,200,000 units will be sold in the year 1936, rising to 77 million units in 1943–44 when the Grid will be fully developed. The average cost per unit is estimated to be 8·5 pies in the completed scheme. With a capital outlay of Rs. 168 lakhs, the gross revenue is estimated at Rs. 19 lakhs.

N. B.—The old tube-well could only lift 3000 gallons per hour, whereas the more recent well can lift 4000 gallons per hour for one unit, the price for which is of 0/2/3 in the wheat season and 0/1/6 in the sugarcane season. Depre-

ciation is allowed at 7 p. c., and interest at 3½ p. c. Oil-engines are difficult to maintain in private wells and cannot be worked continuously for more than 12 to 14 hours a day in the sugarcane season. The introduction of the hydel scheme with its cheap and wide-spread power has led to a large increase in the number of zemindari tube-wells. (Govt. communique, May 1936)

N. B. This chapter has been kindly read and corrected by the Engineer concerned.

The generating and standby plant at present installed is given in Table No. 25 against Nos. 2, 10, 12 and 13, the names of which are printed in italics. The number and size of generators installed at the four power stations are as follows :—

1. *Bahadrabad*, 4 units of 600 kW and 3 of 1000 kW each.
2. *Bhola*, 4 units of 375 kW and 2 of 600 kW each.
3. *Palra*, 3 units of 200 kW each.
4. *Sumera*, 2 units of 600 kW each.

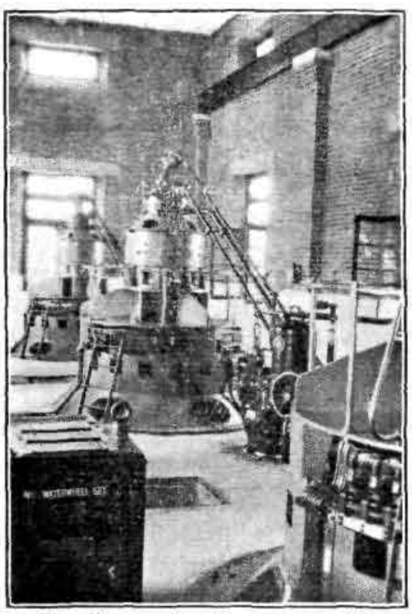


Fig. 24. Generating Sets, Power House, PALRA FALLS.

CHAPTER XII.

WATER POWER PROJECTS OF NORTH-EAST AND CENTRAL INDIA.

The Darjeeling Hydro-electric Installations of 1897 and 1917 are described with illustrations in Chapter X of '*Hydro electric Installations of India*'. The following brief excerpt from Garckes' Manual pertains to this Project :—' Water obtained from 3 small hill Nullahs, tributaries of the Rangeet and Tista rivers, tapped at 5 sites. Minimum flow of sources about 12 cusecs. 2330 volts transformed at station to 230 volts for supply, 2 wire. Mains all overhead, bare copper. Generating Plant,—(a) 4 Gunther's impulse turbines, coupled to 2–65 kW, 1–135 kW and 1–135 kW generators, (b) Gilkes Pelton wheel with 200 kW generator, (c) 1 Hay Marion Pelton Wheel with 200 kW generator, (d) 1 Boving & Co.'s Pelton Wheel with 200kW generator. Total capacity,–1000 kW. Substation–8 transformers'. The figure listed here as Fig. 25 refers to the layout of the Hydraulic works which may be seen in H. E. I. I. Fig. 45.

For descriptions or notes relating to other Hydro-electric Installations or projects of North-East India, please turn to *Hydro-Electric Installations of India*, pages 185 and 186 for Agartula, Tippera and Nepal.

Shillong is the hill station which serves as the summer seat of the Government of Assam. The Shillong Plant works on a head of 1400 feet, has a single pipe or penstock of 2 ft. 5 in. diameter and three generating sets each of 130 kVA and 2200 volts. The distance of the Power Station from the first substation is 2 miles. There are six small substations for distribution of electrical energy at 400 volts for motors and 230 volts for lights. There are 30 to 40 small industries in the city. The Hukong Valley project near the Assam Burma boundary is expected to be good for 65000 kW.

The Kurseong Hydro-electric Supply Company's Installation was opened by the Deputy Commissioner of Darjeeling in Nov. 1933 *vide* Times of India, Nov. 30, 1933. The power station is situated a

few miles north-west of Kurseong. Two 200 kW alternators generate 3300 volts 3-phase 50 cycles per second. They are direct-coupled to Boving water turbines driven by water from the Rinchingtong and Sanyasi rivers. The reservoirs have a capacity of more than 200,000 gallons and are situated 1100 feet above the power units. Current will be distributed to consumers on the 4-wire system, 400 V for power purposes and 230 V. for lights etc. The Company has a contract with the Kurseong municipality for street lighting and other uses, and hopes in future to extend the system and supply power to neighbouring tea factories.

The three falls on the Tons River in Central India (Rewa State) indicate great possibilities but have not been developed as yet for financial reasons. The harnessing of the Pench River (see H. E. I. I. pages 170, and 287) in Central Provinces is under consideration for providing electrical energy to the mills of Nagpur and to the trains between Igatpuri and Bhusaval if the electrification of this section is undertaken by the G. I. P. Ry. in continuation of their existing electric train service from Bombay to Igatpuri. The Tapti River near Bhusaval could give 500 H. P. (see H. E. I. I. p. 287 for particulars). Aluminium could also be manufactured as bauxite and coal occur not far from the water power sites in C. P.

The Parbati River project of Gwalior State is now an ordinary irrigation scheme. Neither this nor other water power schemes of Gwalior described in Chapter XIV of *Hydro-electric Installations of India* have proved financially feasible. Mr. Jeffery writing in 'Indian and Eastern Engineer' for March 1934 on small hydro-electric power schemes has the following remarks to make which seem appropriate for reproduction in the present chapter:—

"The East of India has never availed itself of the many thousands of horse-power that could be extracted from such rivers as the Barak which flows into Cachar with a fall of 3000 feet in about 190 miles and the Manipur State River flowing into Burma with a fall of about 2000 ft. in about 140 miles. There are many rapids and waterfalls on both rivers where power is now wasted on rock and shingle bed erosion only (e. g. the Marjorie Falls comprise 4 drops aggregating 90 ft. in a distance of ½ mile); all these rivers are farther away from Calcutta than the 'Ghats' from Bombay, which make the Tata schemes possible. Calcutta being within easy reach of the Jharia coal fields, promoters of power supply concerns have not the need to search for cheap hydraulic power, but it is a sad reflection to all engineers to know that thousands of horse-power are dissipated

each minute in nothing more useful than the breaking up of rock and pebble beds. Perhaps some day when human existence depends upon cheap chemically-produced manures, foods and metals, a use will be found for all power that is now wasted and we shall find civilisation leaving the plains for the hills where such power exists". It was proposed to produce cyanamide near Jubbulpur, see H. E. I. I. page 233. Nothing is known of the present position of this proposal or of that of Datia State, H. E. I. I. page 185.

In the Annual Industries Supplement of the CAPITAL for Dec. 1933, the present Author began his article with the following words :—

" How often does the saying come true that the last shall be the first and the first shall be the last. Bengal, which began Indian hydro-electric development towards the close of the nineteenth century, has lagged behind the other Provinces and States of India. The Panjab, where minor installations existed when Mysore State and Bombay Presidency had put up big plants and where large-scale development has only now been taken in hand, may be said to have entered the field last of all but bids fair to equal most of the other Provinces and States in India. The Darjeeling plant was put up in 1897. The Uhl River or Mandi Scheme of the Punjab began to give electric supply in 1933. In the year 1929, the Director of Industries for Bengal opined that "in the Teesta River, which debouches into the plains at Sevoke, 13 miles to the North-east of Siliguri, Bengal has a first-class hydro-electric proposition", capable of giving 108,000 h. p.

The western part of Central India and Rajputana are ill fitted by Nature for water-power development as plentiful and perennial supply and large 'heads' of water do not exist together and within comparatively short distances of markets for power. There are few large rivers and the country they go through is largely flat. Big factories are few and far between and they are generally run by oil-engines as coal is either conspicuous by its absence or costly in this region.

CHAPTER XIII.

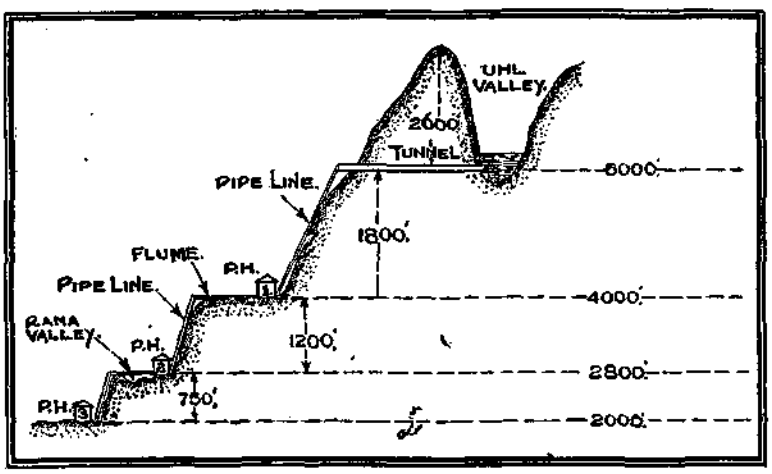
UHL RIVER WATER POWER UNDERTAKING.

he Uhl River Electrical Uundertaking is sometimes referred to as the Punjab Hydro-electric Project because it is the principal water power enterprise carried out by the Punjab Government for the industrial advancement of the people of that Province. It was at the outset and even now is often spoken of as the Mandi Scheme for the simple reason that the Maharaja of Mandi State offered facilities for the carrying out of the Scheme, the headworks and Generating Station of which are situated in the Mandi State, the residential area round about the works has been named Joginder Nagar after the ruling Prince.

Previous Projects in the Punjab

The Punjab is the British Province situated to the North-West of India, bordered by very high mountains to the North-east and the mighty Indus River to the West, but principally comprising vast tracts of plain level or flat country, through which run the five rivers, which have given the province its name of Punj-ab, the vernacular words for Five-Waters. The five rivers are named, the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej. The Province has made great strides in irrigation and agriculture, and is famous throughout the British Empire for its sturdy soldiers. It possesses big canals and favourable situations in the hills for the harnessing of water streams for power purposes. The canal falls so far harnessed for power are described on pages 174 and 175 of '*Hydro-electric Installations of India.*' The Amritsar Installation is on the Upper Bari Doab Canal of the Ravi river which runs on one side of Lahore, the capital of the Province. A fall of only 6 feet is utilised and the power is mainly used for pumping. For further data, please see the next chapter. The other canal-fall installation is at Renala falls on the Lower Bari Doab Canal, a small affair (comparatively speaking) but worthy of note as having been put up for the cultivation of lands belonging to a private individual who was an enterprising engineer,

withal a person who was justly renowned not only for the public and private engineering works which he carried out but also for his many large charitable endowments and institutions. Another small canal-fall scheme is that of the Patiala State, on the Sirhind canal of the Sutlej River. Particulars of this installation will be found in the next chapter. The Patiala State had intended to harness the Sutlej River itself at the Kerithpur loop in its course in the Hills and to utilise 927 cusecs and four falls of 100 feet each in order to develop 31,000 horse-power. The Punjab Government also contemplated at different times harnessing the Anu stream, a tributary of the Sutlej and later, damming the big river itself at Nangal and at Bhakra, but none of these projects have so far been taken in hand. Some information about these schemes can be had by turning to pages 172 and 173 of H. E. I. I. Somehow the Sutlej River seems unfortunate in the matter of hydro-electric development. Its younger brother, the Beas, is the parent of Uhl river, the harnessing of which has put the small State of Mandi on the Hydro-electric Map of India, on which it was not shown hitherto. The Uhl River site was discovered in June 1922, a voluminous Report published in Dec. 1923 and the scheme sanctioned in 1925. A brief description of the scheme, 1925–1933, was published by the Punjab Public Works Department Hydro-electric Branch in 1933, giving information, part of which is contained in the extract from Garckes '*Manual of Electrical Undertakings*', to be found at the end of this Chapter.



Fig, 26. Sectional View, Uhl River Undertaking.

The General Idea of the Scheme.

The site selected for development is situated near Brot, where the Uhl river flows in a south-easterly direction at an altitude of about 6,000 feet above sea-level and has a constant flow of water, the minimum being 112 cubic feet per second. The general idea of the scheme was (1) to build a diversion weir across the river at a suitable spot in the Uhl Valley, (2) to make arrangements for filtration, sedimentation, storage, drainage, over-flow and control of the waters diverted for power development, (3) to pierce through the Dhauladhar Hills, which form a secondary range of the Himalayas and are about 8,000 to 9,000 feet in height and which separate the Uhl valley from the Rana valley into which the used-up waters are passed, the waters are conducted through the tunnel through the hill on to the other side at a gradual slope, (4) to provide safety devices to protect the pipes into which the waters pass from the tunnel down the hill-side, protection is required against breakage, abnormal pressure, falling rocks, temperature variations etc., (5) to convey the waters through the pipes to a power house at a level of about 4,100 feet above sea at the first stage and to another at an altitude of 2,900 feet when the second stage of the scheme is taken in hand and (6) to lead the used-up waters through suitable passages to the Rana river which runs parallel to the Uhl river, about 6 miles to the west of it.

Arrangements to Facilitate Construction.

In order to facilitate the transport of materials of construction and of the men engaged in it, the Kangra Valley Railway was extended a distance of about 100 miles from Pathankot to Joginder Nagar, by the N. W. Railway of which it forms a 2′ 6″ gauge branch. Material had to be lifted 4,000 feet up the side of a hill and lowered 2,000 feet down the other side into the valley. Two haulageways operated by huge winches were constructed to convey the materials aggregating to 115,000 tons from the rail-terminus at Joginder Nagar to the crest of the ridge and thence to the mouth of the Tunnel. The 2-mile gap between the top-ends of the haulageways was bridged with the help of a hill-top tramway worked by sentinel locomotives. This hill-top railway is probably the highest in Asia, the maximum height being 8,300 feet. For generation of the electrical energy required by electric motors driving the various machines used in carrying out the construction works, two temporary hydro-electric stations were put up at opposite ends of the area covered by the works:—one to the North-east at Thuji near the Headworks at Brot and the other to the South-west at Dhelu at the other end. The particulars of these two plants are as follows :—

TABLE NO. 28.

Particulars of the Thuji and Dhelu Plants.

Plant	No. of Units	Volts	kVA Total	kW	R. P. M.	Head	Cusecs
Thuji	1 Francis	400	600	480	750	198 Max.	70
Dhelu	2 Pelton	3,300	1,200	750	750	740	15

Headworks.

The headworks of the scheme are situated at about 6000 ft. above sea-level and consist of the following :—

Diversion weirs, decantation chambers, stilling pond, ducts, forebay, diurnal reservoir, valve chamber, tunnels and surge shaft.

Two separate streams supply the water to the Headworks, thus ensuring continuity of supply of the white fuel which produces the power. The Uhl River as well as its tributary, the Lamba Dug, are dammed at different points a short distance above their junction, to avoid the works being sumberged by floods. The diversion weirs built across them are provided with rail-screens and sluices. The water of the Lamba Dug stream above its weir is brought to the Uhl river weir by means of a 365–ft.—long pipe flume, 4′ 4″ in diameter, through a tilting gate. From this point, the water from either or both of the rivers is admitted to the decantation chambers, 357 feet long, which are provided with scour channels. It is believed that the method adopted here for removing the silt from water and keeping the latter clear by providing sluices below sloping vanes in the bed of the chambers is unprecedented in India. The velocity of the water is reduced to 1 ft. per second, allowing the silt to be deposited on the hopper bottoms whence it is removed by under sluices. The risk of silting within the tunnels is prevented by these precautionary measures. After the decantation chambers comes the stilling pond, 288′ 6″ long. Then the clear water enters the twin ducts of which the western duct only has been laid for the present. This duct is about 1,600 ft. long and 6′ 2¾″ in diameter. It is followed by an upper rapid, 229′ long; an open flume, 243′ long and the forebay, 152 ft. long. These channels are along the right bank of the Uhl river. At the end of the forebay, arrangements have been made for overflow water to be directed through a 2′ 6″–dia. sump pipe to the Uhl river. The water required for power purposes is led from the forebay either to the 8′–dia. pressure duct or through a 330′–long

filling rapid to the diurnal reservoir,-the former method to be employed during summer when the water is likely to be muddy and the latter during winter when it is clear. The pressure duct is laid inside the reservoir. At its other end comes the north or entrance portal of the main pressure tunnel. About 700 ft. from the entrance is the valve chamber. For about 14,000 ft. further down, the tunnel slopes at an average grade of 0·5 p. c. with water inside it running at a velocity of 9 ft. per second. The main tunnel terminates at the surge shaft beyond which instead of one tunnel, there are two tunnels running side by side, held together by a concrete slab, carrying steel pipes inside them, each 6 ft. in diameter and about 1,100 ft. long. Where the pipe-tunnels end, the pipe-line begins. The diurnal reservoir is so-called because it will compensate for diurnal variations in the demand and will supply about 300 cusecs during the day at times of peak load, having stored 150 cusecs during the preceding night for 12 hours. It has a capacity of 7 million cubic feet, is 25 feet deep and is provided with the following :—an overflow and scour-back into the river at its entrance and a screwed off-take near its end, where also are a main sump and a bridge.

Tunnels and Surge Shaft.

The length of the tunnel from portal is 15,308 feet, that is, about 3 miles and its finished diameter is 9 ft. 3 in. It joins the Uhl valley and the Shanan valley. The power house is located near Shanan village. The tunnel was begun on the 1st. of Feb. 1928 and completed on the 1st of March 1932. The record for the distance driven during one month was reached in May 1931 when 357 feet were excavated. The details of its construction were described in a paper presented in Dec. 1932 to the Institution of Engineers (India). Such a pressure tunnel designed for a maximum flow of 900 cusecs of water running at 9 ft. per second lined with cement concrete, mantled with steel and gunited *in situ* for a mile of its length, is believed to be without a parallel in Asia. Two types of lining have been used, a circular lining 12 in. thick for the two ends and a horse-shoe lining 9 in. thick in the central portion, where the tunnel traverses solid gneiss rock. At some places, the men had to work 2,000 feet under the ground and fairly large pipes were run throughout the tunnel to pump in fresh air and force out the foul one. By reversing the air stream, the smoke produced after a charge was fired was quickly sucked into the pipes and driven out into the outer atmosphere. This being done, an electric locomotive shoved forward a mucking machine for picking up the debris and throwing it on to

an endless steel conveyor leading to the trucks. On the Uhl valley or inlet side of the tunnel, there are two mouths, one leading to the valve chamber and the other conveying the water. On the Joginder Nagar end, for the last 1,100 feet, the tunnel branches into two, through each of which runs a steel pipe concreted right up to the exit. At the point of bifurcation of the tunnel, rising towards the surface but bored in the hill-side, is the giant safety valve here styled the Surge shaft as it is a 386 ft. deep concrete-lined well: it is usually called a surge tower or a stand-pipe as it stands up above the level of the pipes or tunnels connected to it. The Surge shaft is 16 feet in diameter at its lower portion and 12 feet at the upper. It serves to diminish the surges in the pent-up waters of the penstocks, thereby saving the pipe-line from effects of abnormal pressure which is produced in the event of a sudden closure of the turbine-valves. It permits the excess water to go out through an overflow tunnel discharging into a Nullah or natural water course on the side of the hill.

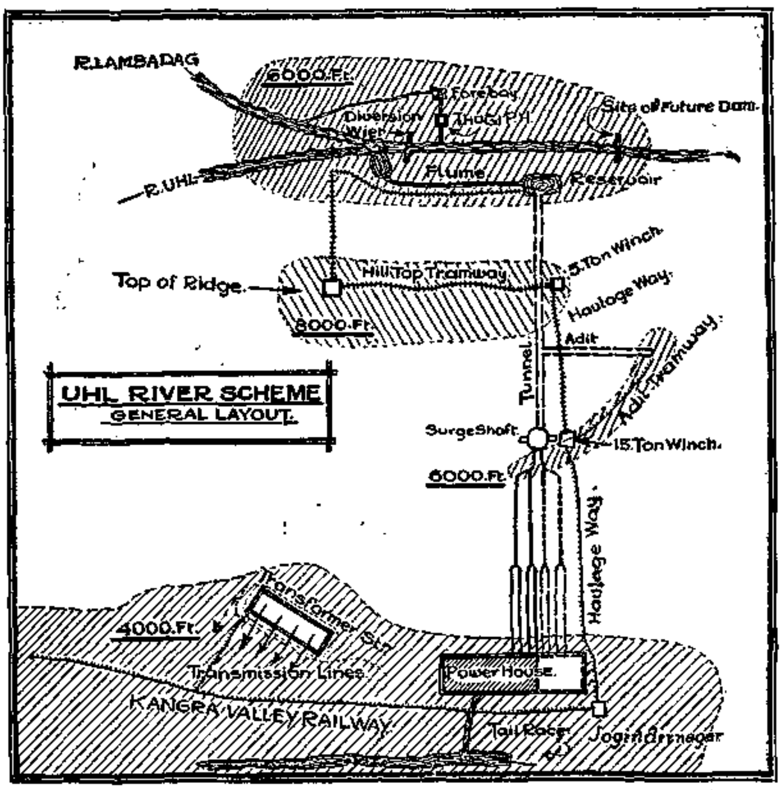


Fig. 27. General Lay-out, UHL RIVER UNDERTAKING.

Penstocks or Pipe-lines.

One of the two pipe-tunnels is blanked for the present, while the other one is bifurcated at its lower end into two 4'7" dia. steel pipes. Each of the latter branches into two 3'7" dia. pipes at the power house where a further bifurcation of each 3'7" pipe into two 2'7" dia. pipes occurs. Each of the last-named pipes carries 100 cusecs of water and supplies it to one water wheel. The pipe-line is 4,556 feet long though the vertical drop or *head* is only 1800 feet. At intervals, expansion joints have been provided against temperature changes causing buckling or breakage,—the maximum temperature being 130° F. and the minimum 32°F. Against falling rocks and lateral pressures due to changes in gradient or direction, anchor blocks have been built to hold fast the pipe line in position. After going through the turbines, the waters are let out of the Power house through the tail-race. At first one half of the pipes provided will carry water for producing power.

Power House.

The power house is an earthquake-proof steel-frame structure with hollow walls and reinforced concrete bracings and buttresses. This kind of construction was necessary in view of the fact that about 30 years ago a severe earthquake affected the Kangra and adjacent districts and States. For the present, four Pelton Wheels are installed of the following description and rating :—single Mitchell-type overhung-bearing, 17,000 h. p. 428 r. p. m. solid steel, 6'6¾" in diameter, with 22 buckets of stainless steel. Each water wheel is direct coupled to a 3–phase, 50–cycle, 11,000–volt, 12,000 kW 13,333 kVA 0·9–p. f., B. T. H. alternator. Three units will be run at one time to supply the full demand, the fourth serving as a stand-by. Four more sets could be installed if and when necessary. A small set has been provided for station requirements at the times when none of the main generating units is running. The usual control boards or switchboards of the type suitable for high-tension apparatus and machines have been fixed apart from the actual switches and electro-magnets or solenoids. The voltage is stepped up from 11,000 volts to 132,000 by means of oil-cooled transformers of which there are two banks, each bank rated at 27,000 kVA or 24,000 kW. These are located out-of-doors on a platform above the power house, along with the H. T. switches and bus-bars. Oil storing and purifying is also done there. The station is only half in capacity, as regards generators and transformers, of what it will be eventually. In addition to

other protective devices, thyrite lightning arresters have been installed.

Transmission Lines.

The high-tension lines going out of the Power Station consist of two circuits, each of three conductors. Each conductor is made up of 30 aluminium wires of 0.102 in. diameter surrounding a core of 7 steel wires of the same diameter in the hilly region, On plains the conductors are 30/0.0935 plus 7/.0935 of aluminium and steel respectively as just mentioned. For the first mile, three conductors on one tower and the other on another tower are carried, thereafter all six conductors on one and the same tower; the two circuits being taken on separate towers again when they are a mile away from the sub-station. Steel towers of 26 types have been used. Hills above Pathankot and the rivers Ravi, Beas and Sutlej have been successfully negotiated. The maximum span is 3,600 feet. The towers are from 100 to 120 feet high. The line-structures are subject to a wind pressure of up to 15 lbs. per square foot. The lengths and voltages for different lines are as follows :—

TABLE NO. 29.

Uhl River E. H. T. Power Lines.

Places	Length (miles)	Voltage (kV)
Joginder Nagar to Lahore (South-west)	173	132
Lahore to Lyallpur (west)	89	66
Lahore to Ferozepur (south)	50	66
Amritsar to Jullundhur	53	132
Jullundhur Sub-stations to Ludhiana	35	33

The 132 and 66 kV sub-stations are of the out-door type as far as their H. T. apparatus is concerned, but L. T. gear and machines are installed in adjoining buildings close to each sub-station. On the Joginder Nagar-Lahore section, there are substations at the following places :—Kangra, Salampur, Pathankot, Dhariwal, Verka (near Amritsar) and Shalamar (near Lahore). The distances separating the power station and the sub-stations are, in the order of places just

mentioned, as follows:—34.3 miles, 43. 25, 31. 3, 32. 2 and 31.1 miles. Besides these six stations of 132 kV apparatus, there is a seventh one at Jullundhur, 53 miles to the south-east of Amritsar, but the line in this case is a single-circuit 132 kV line. The Lahore-Lyallpur section is at present a 66-kV line with substations at Shahdara, 6.5 miles; Sheikhupura, 19 miles; Chuharkhana, 10.75 miles; Mohlan, 20.25 miles; Jaranwala, 19.75 miles; Lyallpur, 21 miles. The Lahore-Ferozepur line is also operating at present at a pressure of 66 kilovolts with a substation at Kasur, 35.75 miles away and another at Ferozepur, 15.75 miles from Kasur. About 40 miles. from Amritsar, Kartarpur will be fed from the Amritsar-Jullundhar line. The Jullundhur-Ludhiana line carries current at 33 kV, with substations at Goraya, 18.88 miles and Ludhiana 16 miles farther on. A 22 kV line connects Joginder Nagar with Mandi, 20 miles south. All the above-mentioned stations are Grid substations with local distribution at 11 kV. From Kangra,a 11-kV line goes to Dharamsala. 11-kV lines also go out to other places as indicated below :—From Dhariwal to Gurdaspur, to the north; to Qadian, to the south and to Batala to the south-west; from Gurdaspur to Dina-nagar; from Amritsar (Verka) to Amritsar water works and Sultan-wind gate and thence to Tran Taran to the south, to Amritsar Power House and Hakimanwala gate to the south-west and to Amritsar Central workshops (not yet constructed) and Chheharta to the west; from Lahore (Shalamar) to Sadar Bazar Ice factory and Canal to the south; from the Canal, to Ichhra to the north and to Model Town and Gulab Devi Hospital to the south; from Shalamar (Lahore) to Moghalpura to the south-west (11/3.3 kV) and to Baghbanpura to the west; from Mohlan to Nankana Sahib; from Goraya to Phagwara to the north and to Phillaur to the south. An area of 46,000 miles equivalent to that of Great Britain and a population of one and a quarter million will thus be served by electricity. The design of the Shalamar sub-station is in accordance with that adopted by the Central Eectricity Board of Great Britain and owing to a mesh or ring system of bus-bars enables any apparatus in the H. T. circuit to be fed from either direction or disconnected for repairs or overhauling without causing interruption of supply to other pieces of equipment. There is a Switchgear Yard for 132 kV transformers, lightning arresters, circuit breakers etc. and another one for 66-kV apparatus,—all installed-out-of-doors. Railway tracks and cable trenches connect these yards with the Moghalpura siding and the Control Room respectively. Next to the Control Room are the switch and condenser houses,—in the latter two synchronous condensers are installed to improve the power factor and Tirrill regulators keep the voltage constant automatically in spite of

fluctuations in the load on the system. Not far from these houses' there is a building where oil used in transformers, breakers etc. is pumped and filtered. On the other side, not far from the side gate, an automatically-controlled electric pump draws water from a 6″ tube-well to supply station needs. The two transformers in the 132–kV yard lower the voltage to 11 kilovolts and two transformers in the adjoining yard lower it to 66 kV. One transformer of each kind serves as a stand-by. In all the 132–kV sub-stations, relays are provided to isolate a faulty line automatically,—duplicate bus-bars and sectionalising switches enable the supply to be maintained over the other line and bus, so that there is no interruption in the supply to consumers.

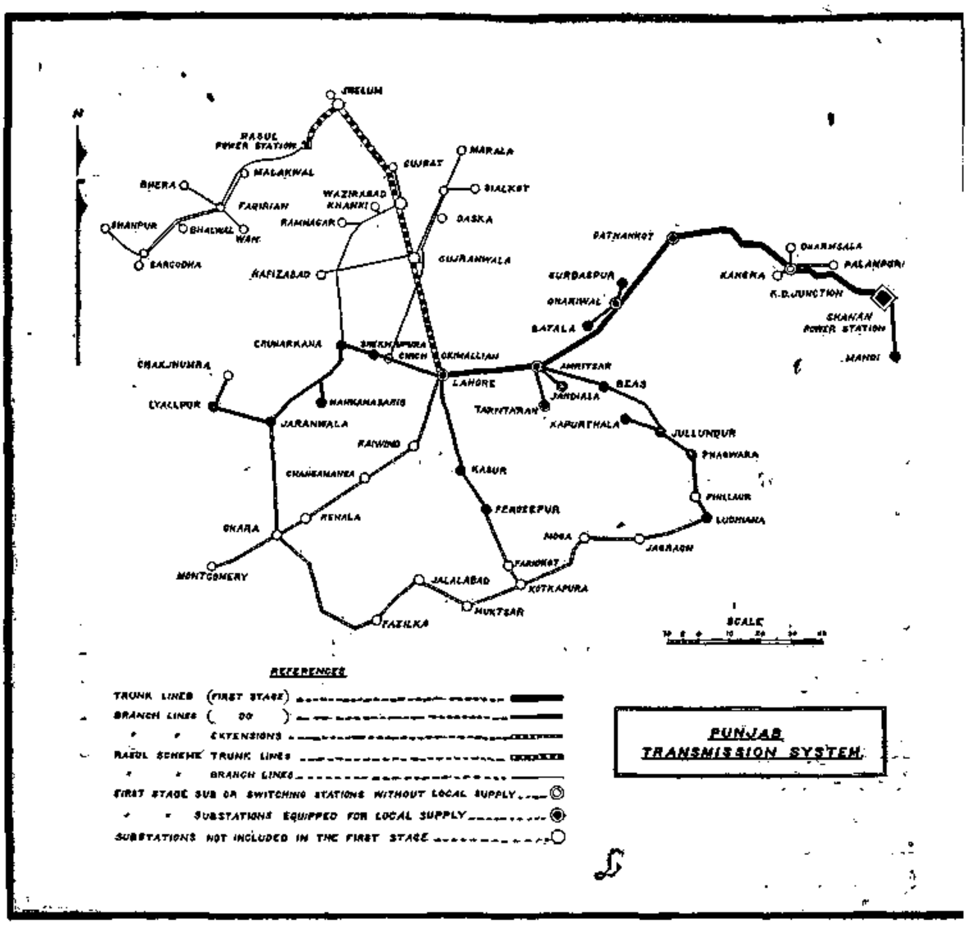


Fig. 28. Transmission System, Uhl River Undertaking.

The altitudes of the different works are as follows :—

TABLE No. 30.

Uhl River Works, Altitudes.

Place	Elevation above sea-level (feet)
Headworks	6,125
Tunnel entrance	5,897
Present Power House	4,141
Second " "	2,920
Third " "	2,100

The Cost of the Scheme is stated to be about 7 crores of rupees.

Bulk supply to the Indian States of Kapurthala, Faridkot, Malerkotla is under negotiation. When the load rises as it is bound to do with the facilities provided and promised to licensees, the revenues will steal a march over the expenses and the scheme is sure to prove a success from a financial point of view as well, as it is already from other standpoints, particularly the industrial advancement of the people of the Punjab who have loaned the money.

I. *Indian Engineering*, Sept. 23, 1933, says:—

I. This is the first Government undertaking to supply electrical energy direct to urban consumers,.........also the first in India to transmit energy at 132,000 volts.

Existing licensees will receive energy in bulk for distribution at Lahore, Amritsar and Jullundhur, also the N. W. Railway at Lahore for its own premises and purposes. Bulk supply to Kapurthala State is under negotiation. Supply may be extended to Faridkot, Malerkotla and Nabha States.

II. *Indian Engineering*, March 18, 1933.

The scheme will earn in 12 years 61 lakhs, yielding a surplus of 3 lakhs. Its primary object is to give practical effect to the desire that Government should help forward industrial development of the

Punjab by giving plentiful supply of cheap power over a wide area. It will supply 133 million units at a rate 2 pies cheaper than any thermal plant i. e. about 14 lakhs cheaper. Energy will be distributed to 14 towns.

III. *Indian Engineering*, May 14, 1932.

The Uhl River Scheme was begun in 1926. Interest upto 31-3-1930 was charged to capital cost as is the customary procedure. After that date, interest is being charged to Provincial revenues.

The following extract from Garckes' *Manual of Electrical Undertakings* 1933-34 refers to the Mandi Hydro-electric Scheme :—

Utilises difference in level of two rivers—the Uhl and the Rana.

The Uhl River flows S-E and is paralleled at a distance of about 6 miles westwards by the Rana river flowing in the same direction at an elevation 3000 feet lower. The two rivers are separated by a spur of the Dhauladhar Range, the crest of which runs parallel to the Uhl at a distance of about 1 mile from the river-bed. Thus there is a steep rise from the Uhl to the ridge and a slope of about 5 miles down to the Rana. Water from the Uhl River is conveyed by a circular tunnel of 9¼ feet diameter about 2.6 miles long and developing the power in stages on the slope towards the Rana. The tunnel is designed for a discharge of 600 cusecs falling through pipes 8,800 feet to the power House at Jogindernagar in Mandi State, about 200 miles N-E of Lahore. Initial capacity of station 48,000 kW (64,000 H. P.) by four 16,000 H. P. 428 r. p. m. turbines each driven by a single jet of water and connected to a 12,000 kW 11,000V alternator. *System.* Double circuit trunk transmission lines 132,000 V to Lahore 173 miles; branch lines Amritsar to Ludhiana 88 miles, Lahore to Lyallpur 89 miles, Lahore to Ferozepore 50 miles. Supply in bulk to existing licensees at Lahore, Amritsar, Jullundhur and to North-Western Railway at Lahore and thirteen towns, to be given direct retail supply. Permanent works such as pressure tunnel have been constructed to meet the needs of a generating plant of 120,000 kW while the hydraulic works in the Uhl valley, where the maximum discharge available has been estimated at 70,000 cusecs, have been designed to suit a variation in flow of about 900 to 1. When developed to its third and final stage, the scheme will rank as one of the major schemes in the world, ranking in India second only to the three Tata schemes in Bombay.

Fig. 31 is a transverse section showing the levels of the different works and power houses. Figures Nos. 26, 27 and 28, re-

produced from blocks kindly supplied by the Editor of *Electrotechnics* No. VI, pertain to the Uhl River project. Fig. 26 shows a sectional view of the development through the Dhauladhar range. In it are indicated the altitudes of the Uhl Valley and its neighbouring highest peak, of the tunnel, pipe-line, power houses Nos. 1, 2 and 3, and the Rana valley. Fig. 27 is a diagrammatic sketch of the general layout of the scheme, indicating the relative positions of the temporary power house at Thuji, the rivers Uhl and Lambadug, the diversion weir, flume, reservoir, hill-top and adit tramways, winches, haulage-ways, tunnel, surge shaft, pipe-lines, power house, tailrace, transformer station, transmission lines and Kangra valley railway. Fig. 28 is a map of the Transmission System showing the portions of the Punjab province covered by the power lines emanating from the various stations of the Uhl River Undertaking:—the thick lines are the trunk transmission lines and the thin ones the branch lines of the first stage of the Uhl system, the circles of different kinds represent sub-stations of various sorts. Extensions to Branch lines are also shown in this map. A more interesting point that follows from a study of this map is that the present transmission system is to be linked with that of the proposed Rasul Power Station which is shown as located between the towns of Jhelum and Malakwal. Reference to page 173 of 'Hydro-electric Installations of India' is suggested for further particulars regarding 'head' and 'power' to be developed, though exact data would only be known after it is decided to proceed with the Rasul undertaking. The map, Fig. 28, shows transmission lines of the Rasul as well as of the Uhl systems, and one is therefore perhaps justified in infering from it that the Punjab Electricity Department intends to develop the water power possible from the canal falls near Rasul and perhaps other places in the North of the Punjab, one after the other as the financial condition of the Province improves in the future.

N. B. This chapter has been kindly read and corrected by the Engineer concerned.

CHAPTER XIV.

OTHER WATER POWER PROJECTS OF NORTH-WEST INDIA.

The description, with illustrations, of the original Malakand Water-power Plant on the Swat River canal appears in Chapter XII of '*Hydro-electric Installations of India.*' Fig. 30 of the list in this book referring to the Malakand vertical generators may be seen in H. E. I. I. (Fig. 55).

A new project has recently been launched by the North-West Frontier Province, which is estimated to cost about Rs. 52 lakhs to be met by a subsidy from the Government of India. The present Malakand tunnel will be extended to give a fall of 250 feet. The generating machinery to be installed at the upper site of the 2 sites, 4 miles apart, suitable for development, in the first stage, will make power equivalent to 20,000 kW available and cost about Rs. 7½ lakhs. The scheme is expected to be completed by the end of 1937, within three years, but expenditure is likely to be spread over 9 years. The rates for lighting and rural machinery are to be 4 annas and one anna per unit respectively. The main consumer will be the Army, as it will take power required for the cantonments of Risalpur, Nowshera and Peshawar. The North Western Railway and the Peshawar City Electric Supply Co. are expected also to take bulk supply from the Hydro-electric Station. Three 3200 kW 11000 V 3-phase sets will at first be installed. Voltage will be stepped up to 66,000 V for transmission to Mardan, Charsada, Peshawar and Risalpur and to 110,000 V for more distant sub-stations. For 32 miles, there will be a double-circuit, for 70 miles a single-circuit line. Distribution will be at 400 V for 3-phase appliances and 230 V for single-phase. The lower site near Dargai (also a 250 ft. fall) will generate another 20,000 Kilowatts.

The *Patiala State* Installation at Nidhampur is briefly described on page 180 of *Hydro-Electric Installations of India.* The following extract from Garckes' *Manual of Electrical Undertakings*, 1933-34 refers to this installation :—

TABLE NO. 31

Patiala State Plant, supply statistics.

Water Power Plant at Nidhampur, 213 kW.

Steam reserve, 600 kW.

Two sub-stations (one additional under construction)

System. Generation, 3-phase 50 cycle, 400 V.

Transmission, 10,000 V through three 250 kVA M-V transformers.

Distribution at 230 and 400 V.

Supply statistics. Load connected 400 kW.

Maximum recorded, 320 kW.

Consumers in addition to the Hazuri, 540.

Prices charged—lights and fans, 6 annas, power 3 annas per unit, 2 annas above 5000 units.

The Simla Water Power Plant at Basantpur is described at length with illustrations in Chapter XI of '*Hydro-Electric Installations of India.*' The following extract from Garckes' *Manual*, 1933–34 refers to it :—

Plant–540 ft. head from Nauti Khad, tailrace discharging into the Sutlej River. Minimum perennial flow, 19 cusecs. Storage, about 8 hours supply in reservoir above pressure pipes. Pipe-line 1300 feet. Boving Pelton wheel, three 450 B. H. P. and two 900 B. H. P. with Siemens alternators 250 kW and 500 kW respectively. Total capacity 1750 kW. Water pumped up 2640 feet to a point from which it gravitates to Simla.

TABLE NO. 32

Simla Plant–Supply statistics.

Public lamps 1100 (60 to 200W, M. F.)

No. of consumers 4300,

Maximum load 1425 kW,

Total connections 2800 kW,

Load factor 42·5 p. c.

Prices charged, Lighting 6 annas per unit.

Power 2–1$\frac{3}{4}$ annas per unit.

Heating $\frac{1}{2}$ „ „ „

For the following revised figures bringing the description of the Simla scheme to date, the Author is indebted to Mr. R. L. Narayanan :–

The depth of the Flume is 4 feet now. The minimum discharge of the Nauti-Khad fell to 7 cusecs in 1932 during the daytime when

the cultivators above the weir were taking water for their fields and to 12 cusecs at night when they were shut off according to agreement with the State. The maximum flow in the flume utilised now is 45 cusecs. To supplement the supply from the Hydro-electric Scheme a Diesel station was erected at Simla in 1928. It has an installed capacity of 550 kW., there being two sets of 275 kW. each. The engines are of Mirlees Bickerton and Day's make and the alternators of Metropolitan Vickers' manufacture. The energy generated at Chaba is now about 6 *million* kW-h. and at the Diesel station in Simla it varies with the nature of the dry season in April-May, but an average of half a million may be assumed.

Supply is now given to a third pumping station at Guma located on the same Nauti Khad, situated between Chaba and Chair. The plant here consists of two reciprocating pumps each driven by a 1000 h. p. motor and pumping water to a head of approximately 4000 ft. static and 4400 ft. inclusive of friction head. The population of Simla during the season is now about 52000. The pumping load is so arranged to run that as far as possible it fills the valleys of the load curve.

The proposed 50,000 kW power station at Rasul on the upper Jhelum canal shown in Fig. 28 along with the Joginder Nagar Station and system will enable Northern Punjab to electrify its industries and cities.

The canal-fall power installation put up in 1916 on the upper Bari Doab Canal near Amritsar has been described on page 175 of "Hydro-electric Installations of India" and the following figures from Garckes's Manual of Electrical Undertakings for 1934 relate to it :—Plant capacity 525 kW. Distribution voltage 500, Load connected 200 kW, Maximum load 180 kW, Units generated per annum 500,000. The illustration accompanying this chapter, Fig. No. 29, shows the Amritsar Water Power Plant; it was not available when H. E. I. I. was published. The Madhopur Scheme to harness the waters of the Ravi river by creating 75 ft. falls on the Upper Bari Doab canal in its head-reach to develop 34000 kW has not materialised.

The Renala fall-installation of the late Sir Ganga Ram put up in 1922 on the Lower Bari Doab Canal has already been referred to in the previous chapter. It produces power for various agricultural operations requiring power and for lift irrigation, besides the usual purposes of illumination and ventilation; capacity of plant installed, 1100 kW; head, 7 ft. Latest information about the other falls on

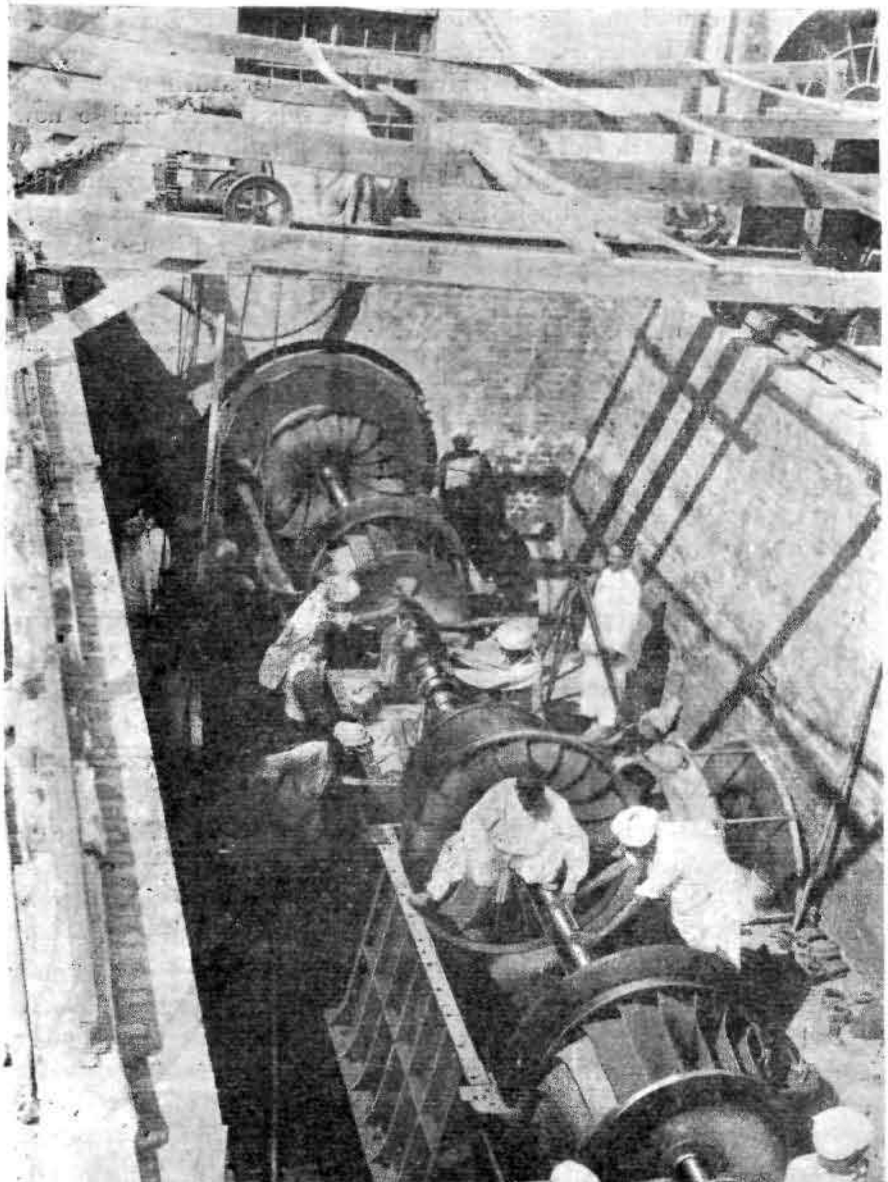


Fig. 29. Generating Sets, AMRITSAR WATER POWER PLANT.

the Upper Bari Doab and the Chenab canals referred to on pages 173 and 246 of 'Hydro-electric Installations of India' is not available and it does not seem likely that the Madhopur scheme of the Upper Bari Doab Canal of the river Ravi or other schemes sponsored by private concerns or associations are likely to materialise now that the Government of the Punjab have taken it on themselves to undertake projects for the provision of electrical energy in that province. The harnessing of Upper Jhelum and Upper Chenab canals could provide power for North Punjab. "If ever the Chenab Hydro-electric Plant is started at Riasi, the bauxite of Kashmir can be the source of all the aluminium that India needs", Indian Electrical Times, July 1934. Just outside the north-west Frontier, in Afghanistan, there is a hydro-electric installation at a place, in the mountains appropriately named Jabbal-Sarai where by utilising a head of about 200 ft., 500 kW is produced to be delivered 40 miles away at Kabul, the capital of the country of the Afghans.

A small water power plant for the Sirmur State which has its capital at Nahan, in the centre of East Punjab, was proposed by Mr. S. K. Gurtu, M. I. C. E.

"According to the latest administration report, there was great electrical progress in the Punjab in 1935, and the total installed generating capacity *excluding* that connected with the Uhl River Hydro-electric project rose from 9000 kW to 22,000 kW; the number of the licensees increased from 23 to 43 and the number of units sold rose to 25,800,000.

The total generating capacity of the Uhl-river hydro-electric project remained at 48,000 kW as before and the number of units sold was 8,500,000. The rates of the Lahore Electric Corporations were reduced during the year, resulting in a considerable increase in load.' (Electrician, March 27, 1936).

In September 1936, the load had increased to about 20,000 kW and the number of units generated daily rose to 103,000; the number transmitted during the year being about 23 million units on the 132 kV system.

No water-power plants exist in Sind where water is abundant in the Indus River and its canals but sufficient 'head' is impossible because of the level nature of the land. Baluchistan, where high heads are possible, also is backward in the matter of water-power development because of the paucity of water. Quetta in North-west India and Mount Abu and Pachmarhi in Central India have no hydro-electric installations, though they are important hill-stations,

CHAPTER XV.

THE PYKARA RIVER POWER PROJECT.

The Pykara River is one of the largest of the rivers draining the plateau of the Nilgiri Hills or Blue Mountains of the South of India. Its source is situated at an altitude of about 7,000 feet on the slopes of the Mukuruthi Peak, about 12 miles west of Ootacamund. On its way to the site of the present works (about 15 miles from its source), the Pykara is enlarged by the waters of small tributaries from the Porthimund, Mukurti and Parsons Valleys where sites suitable for reservoirs for future developments exist. For the present, these are not required, as the South Indian Railway has decided to electrify only its suburban lines near Madras City but not its main lines. The height above sea level of the site of the works is 6,000 ft. and not far from this site, there are two falls, the combined drop of which is 4,000 ft. The present Project utilises only 3,000 feet of this drop; the remainder of 1,000 ft. is to be developed to give 30,000 h. p. at a later date if necessity arises. This future scheme will be named the Moyar Scheme to distinguish it from the present Pykara project, but it may be pointed out that the Moyar river is only the Pykara under another name, at an altitude of 2,000 ft.

A. GLEN MORGAN INSTALLATION.

To provide power for the Pykara project works-the first stage of which has been recently completed-the power house having been inaugurated on April 5, 1933, there existed an auxiliary hydro-electric installation, which might be mentioned briefly at the outset. This subsidiary 1500 H. P. scheme styled the Glen-Morgan Scheme was completed in Nov. 1929 to supply the electric power required for the construction works being then built in connection with the principal Pykara Project. The Glen-Morgan site is at a short distance from that of the Pykara Works and the small plant installed there furnished power not only for the construction works but also for the bungalows, streets and factories of Ootacamund and Coonoor. The water used at the Glen-Morgan Hydro-Electric Power House was that of the Pykara river and was brought to

the generating station after being first diverted by a small weir just above the first fall, then led through an Armco flume and finally dropped down the penstocks to the turbine. Fig. 33 shows the relative position of the hydraulic works of the Pykara Glen-Morgan Power development. The Head of water utilised for the subsidiary scheme was only 680 ft. The small plant was of great assistance to its big brother in accelerating the progress of the construction works. Besides the line to the works, the 11,000-volt transmission line from Glen-Morgan to Ootacamund was already in existence. The Pykara scheme was begun in January 1930 and completed in March 1933. It has been carried out by the Madras Government.

B. STORAGE RESERVOIRS.

Reverting now to the Pykara project proper, we should state at the commencement that the catchment for the rainfall from both the South-West and North-West Monsoons is 38 square miles in area and the average rainfall is 78·55 inches per year. For continuous supply of a definite amount of power, it is necessary to store the precipitated waters in reservoirs, otherwise enough power would not be available during seasons of low water in the rivers receiving the water off the catchment area. The minimum flow might suffice for small schemes like the Glen-Morgan one, which is now rendered superfluous, the Pykara plant having started supply of electrical energy, but it will be entirely inadequate for any large-scale scheme. The present Pykara project provides for the ultimate utilisation of power equivalent to 30,000 kW continuous or 60,000 kilowatts with a load-factor of 50 p. c. This corresponds to a discharge of 150 cubic feet of water per second, whereas the least water flow is only 15 cusecs and would suffice only for 3,000 kW *ex*-generators. The figures just given are inclusive of storage available from the Glen-Morgan and the Sandy Nallah streams (which are close to the Pykara river) and refer only to the main head of 3,000 feet. From the main reservoirs which at present store about 84 million cu. ft. and the number and capacity of which could be increased up to 3,000 million cu. ft., as and when demand for power rises, the water is led to the regulating reservoir, usually termed the Forebay. There are two sources of water coming to the Forebay. In other words, two dams divert the water to it; one in the West, one mile above the Main Fall, across the Pykara river, the other in the east across the Glen Morgan stream. It is always an advantage to provide two independent sources of water, so that the forebay will never be deprived of water altogether. The Pykara

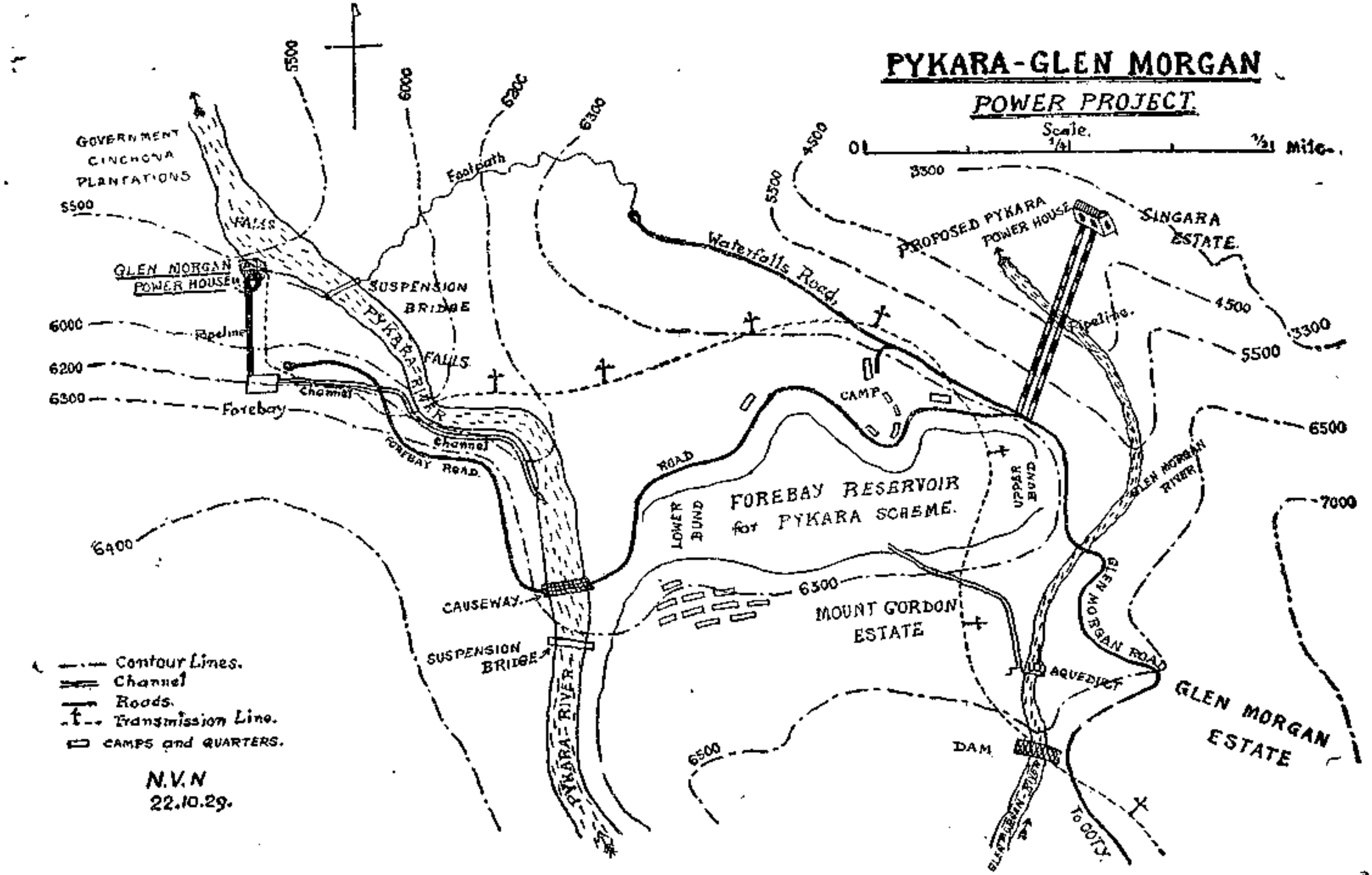


Fig. 33. Hydraulic Works, PYKARA–GLEN MORGAN PROJECT.

diversion Weir has 2 main and 2 subsidiary spans. River level can be raised 18″ by stop-logs. The supply channel from the Pykara Headworks to the Forebay slopes very gently so as not to lose head of water and consists of a 7,000 ft.-long flume or channel consisting of open cutting, aqueduct and steel conduit supported on trestles. Further on, it is lined with reinforced concrete for 1500 ft. up to the Forebay. There are two Bunds, known as the Upper and the Lower Bunds of the Forebay; the former 43 ft. high and the latter 65 ft. high, on the upstream side. The quantity of water that can eventually be stored in this storage tank is 58 million cubic feet; the Glen Morgan reservoir being meant for 26 million cu. ft. Surplus water from the forebay rejoins the parent river, the Pykara. The Forebay is situated at a beautiful spot on the edge of the Nilgiri plateau and overlooks the Chamundi Hills of Mysore City in the distance near the horizon. Fig. 32 is a profile diagrammatic view indicating the two streams, weirs, reservoirs and bunds, as well as the forebay, surge tower and penstocks. (The block for Figs. 31 and 32 was kindly lent by the Journal of Association of Engineers. It appeared in its June 1933 issue).

C. PENSTOCKS.

An electrically or manually operated gate lets water into a 240 ft. long *tunnel* from the forebay and then into the penstock of riveted steel, 1,100 feet long and 78 inches in diameter. There is a sluice valve where this pipe starts, and a 6 feet diameter Surge Tower, 65 feet high and 6 feet in diameter, where it ends. The valve at the Surge Tower is electrically operated from the Power House. Venturi meters have been fixed to measure and record the flow in each pipe. A little distance down from the Surge Tower, the upper penstock bifurcates into two high-pressure pipelines, each 10,220 feet long and varying in diameter from 27 inches at the top to 21 inches at the bottom of the whole pipeline. Each piece of pipe is 20 feet long and is supported on saddles. There are 28 anchor blocks of re-inforced concrete, one for each place where strengthening of the pipeline is considered necessary, for example at every change of grade or of direction. Expansion joints have also been provided against changes due to temperature variation. From anchors Nos. 28 to 21, the diameter of the pipe is 27 inches, from Nos. 21 to 10, 24 inches and from anchor No. 10 to the final anchor at the point nearest to the Power House at Singara, the pipe has a diameter of only 21 inches. On the other hand, the thickness of the lower sections is greater than that of the upper sections of the pipeline varying from 11 mm. to 16·2

and from 16·2 to 27 mm , as the pressure of water, which the different sections have to withstand, increases as we go down. The pipes are seamless and of high carbon steel. Each of the three sections of the pipelines between the anchors just specified is a little more or less than 3,000 feet long. At the power house, the pipelines terminate in a manifold pipe which has three 16½ in. branches in order to supply water through separate inlets to the three main turbines installed in the generating station. Provision has been made for two 48 in. penstocks for future extension. The vertical head of water is computed at 3,060 feet, whereas the total distance along the hillside from the forebay to the power house is about four times the head. Assuming a continuous flow of 150 cusecs, this head would give theoretically (150x 3,060 divided by 15) kilowatts, that is, 30,600 kilowatts approximately at the generator terminals. As for the pressure of water at the turbines, it may be calculated by dividing the head by 2·3, thus giving a pressure of nearly 1,300 lbs. per sq. in. The reader who is interested in the methods of calculating the quantities just alluded to will find the formulae and explanations of them in the Author's book on *Hydro-Electric Installations*, Chapter II, pages 26 and 27, where several examples are solved, with the statistics pertaining to the other Indian Hydro-electric Installations. A perusal of this volume would bring home the points of similarity and dissimilarity between the Pykara and other installations, but the striking feature of the Pykara Project is the unusally large drop of water developed viz. 3080 ft. which makes it unique not only in India, but in the British Empire. The cost of the Pykara pipeline is about 18 lakhs of rupees.

D. POWER HOUSE.

Men and material are transported from the Forebay bank to the Power House at Singara by means of trolleys running on rails and hauled by stranded steel ropes, wound on drums by three-phase 400-volt induction motors of 75 or 50 h. p. each. This voltage is obtained from either of two station transformers installed in the Power house, which is situated not far from the Masinigudi village. Fig. 34 shows generating units in the Power House. Each of the three main turbines coupled to generators is rated at 10,900 h. p. at the net head of 2,800 feet, is meant for 1140 litres of water, is of the Escher Wyss Impulse type, has a wheel of diameter equal to 72 inches and revolves at a speed of 600 revolutions per minute. Its speed can be controlled by means of an oil-pressure governor which can be operated either by hand or by an electric motor. The

main nozzle is 5 in. in diameter and the brake nozzle 2 in. in diameter. the inclination being 15°. The water can be deflected so as to strike downwards at the pit wall and the turbine can be stopped within 10 minutes.

Direct-coupled to each turbine is a Metro-Vick Alternator rated at 7,810 kilovolt-amperes, 11,000 volts, 3-phase, 50 cycles per second, good for 6250 kilowatts at ordinary power factors. Each alternator has a direct-coupled exciter, mounted on a separate bed-plate, rated at 110 volts direct current and capable of furnishing upto 500 amps, for the revolving field coils. The exciter has been so designed as to take care of the effects of the charging current of the transmission line on the pressure or voltage at the generating Station. A three-phase reactor immersed in oil has been installed in each of the two cables to the 11-kV bus, to guard against serious consequences of short-circuit of the alternator and is rated at 11000 volts, 105 amps, and 0.86 ohm per phase. There is also an auxiliary on-load tap-changing transformer in the station. To safeguard against earth-leakage, over-voltage, over-current, circulating currents etc. relays and automatic Switches have been provided. Tirrill regulators serve to maintain the voltage constant automatically. A frequency clock has also been fitted up near the Switchboard. An electrically-worked CO_2 fire-extinguisher stands on the generator floor. Those who are interested in the details of fire protection of electrical generating stations would do well to see Mr. Gilbert's article in the August 1934 number of '*The Indian and Eastern Engineer*'. Automatic alarms have been installed to intimate danger due to stoppage of oil or water, or due to overheating of bearings or windings. Meters necessary for registering hydraulic and electric quantities of various kinds e. g. head, pressure, speed, current, voltage, frequency, power, power factor, energy, synchronism etc. have been fitted wherever required. The generator neutral is earthed through a resistance of 13.5 ohms; the main transmission neutral is earthed at the power house. A 250 kVA 11000/400 Volt transformer to supply power for local requirements is installed at the power house. The building is 45 ft. high, 127 ft. long and 54 ft. wide. It is a strong structure of masonry in cement mortar, with a water-proof roof and ample arrangements for ventilation. Space exists for the installation of four 17000 h. p. sets in the extended Power House in the future. The tailrace waters join the Glen Morgan Stream at first and then the parent river. As stated at the beginning of this chapter, the Glen Morgan Installation used to receive its water from the Pykara river and return the same after

developing power to the same river. The Singara water will probably be used alongwith that of other streams to generate power at a Power House to be located on the Moyar River, where two 15000 h. p. sets will be installed if the scheme matures.

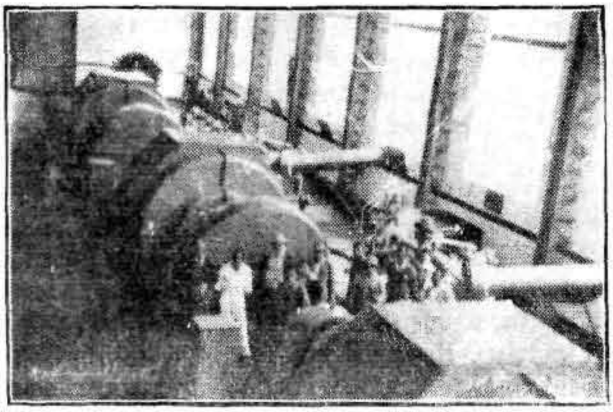


Fig. 34. Singara Power Station: Generating Plant.
PYKARA.

E. TRANSFORMER STATION.

A little distance outside the Power House, a steel-lattice two-storied Outdoor Transformer Station has been built, where three 7810 kVA transformer banks have been installed to step up the voltage to 66 or 110 kilovolts. The windings are connected delta-star. Choke coils and lightning arresters have been installed to protect against atmospheric disturbances. The H. T. Oil circuit breakers are also of the outdoor type. There are six bare H. T. conductors, each of 6 stranded aluminium wires, each. 0.208 in diameter with a central steel core of 7/0.069 in. diameter. The steel ground wire over them used for protection against lightning is 3/8 in. in diameter. The conductors are spaced 9·5 ft. apart vertically and 17 ft. horizontally with an offset of 2.5 ft. in the middle conductor in hilly regions. Each conductor hangs under a string of 5 disks of suspension-type insulators for the present pressure of 66 kV. The number of disks will be increased to 8 when the pressure is raised to 110 kV. On long spans, 8 disks have been already provided. Lightning arresters are of the Oxide-film type, installed out of doors. At the power-house end the lines are fitted with directional selective earth-leakage relays and inverse time-characteristic relays and at the receiving end, with reverse-power relays.

F. TRANSMISSION SYSTEM.

From Singara, the H. T. lines go over steel towers or pylons to Coimbatore, fifty miles away. The standard height of the towers is 75 ft. There are 229 of them in the 59 mile length, normal span 1050 ft. A separate double-circuit telephone line runs parallel to the power line, which is also double circuit to ensure continuity of supply of power. The maximum span is 2670 feet. From Coimbatore, power is passed on to Tiruppur and thence to Erode, length in each case being 29 miles. The H. T. aluminium stranded conductors for the lattar two circuits are carried on single towers, normally 50 ft. high and 750 ft. apart. The line pressure here is at present 22kV. This is also the pressure for the lines from Coimbatore to Pollachi, 66 miles away, the double circuit being carried over wooden poles and continued as a single circuit to Iyerpadi in the Annamalais to work the tea and coffee estates and factories. Peelamedu and Palghat will be supplied over similar lines, as also the city and mills of Coimbatore. The crossarms for L. T. lines are of the V type to guard against large birds. At the higher pressure of 66 kV, power will be sent on from Erode to Trichinopoly (82 miles away) and Golden Rock where the S. I. Ry. workshops are located, and eventually to Ernakulam. Power may be sent in future to Calicut and the Wynad. From Erode, power at 22 kV will be sent to Salem and Mettur (68 miles) and at 66kV to Trichinopoly and to Negapatam via Tanjore until the Mettur Dam Installation is completed. Two 11/22 kV lines which had been put up in connection with the Glen Morgan Scheme are now used to deliver Pykara power to Ootacamund Receiving Station for distribution in Ooty, Coonoor, Wellington and other hill-towns on the Nilgiri plateau. Two feeders off the L. T. bus of the Power Station supply power to Devershola and the Camp near the Forebay and to Prospect.

G. RECEIVING STATIONS AND SUBSTATIONS.

Two feeders emanating from the 11000 volt Bus of the Generating Station go to the Receiving Station at Ootacamund, which is about 15 miles away. Three single-phase transformers connected in delta-star, 11000/5000, each 200 kVA, 50 cycles per second are installed in this Station. Four feeders go out of this building to deliver power at 5000 volts. Constant-current transformers with movable secondaries change 5000 volts to about 2000 volts for about 300 6·6 amp. 60 watt street lights. To provide against a failure of the series system of lighting, 25 lamps at important points are connected in parallel. The holders for the series lamps are

provided with paper-insulation which punctures if the lamp burns out, with the result that the circuit is automatically remade and the other lamps continue to give light.

The Ooty Station is an ordinary building where the transformers etc. are installed indoors, but the main Receiving Station of the Pykara System is at Coimbatore, where all apparatus is installed out-of-doors, the busses being, however, lower than at Pykara.

The Coimbatore Station receives power at 66 kV and steps it down to 22 kilovolts by four delta-star English Electric transformers of 3000 kVA each, for supply to places not too far off. The high-tension distribution neutral is earthed only at the main substation. The low-tension neutral is earthed bare, in small towns and rural areas and serves also as the earth wire for the substation. In a small building, close to the Coimbatore Receiving Station Outdoor Kiosks and structures, are installed the following appliances :— Testing apparatus for H. T. oil etc., 300 amp-hour battery of 60 cells, motor-generotor 11000/400 volt station transformer and switchboard for switches, instruments, relays etc. It is expected that several cities and towns now supplied by thermal stations will in the near future begin to take bulk supply of electrical energy from the Coimbatore Station, which supplies power to Cotton Mills, Cement Works and Municipality of the city. "Oil engines taken from mills (now worked off hydro-electric supply) have been re-erected in outlying areas to enable loads to be built up, pending extension of the transmission system" "80% of Pykara power will be consumed in textile, cement, tea and cottage industries and 20% for lighting and domestic purposes." *Electrician*, 23-8-34 and 29-9-33.

The Erode Receiving Station is also an out-door station (Fig. 35), which receives power on 2 circuits from the Coimbatore Station. From the Erode Receiving Station, power is passed on to the S. I. Railway Substation at Erode, whence it goes to Trichinopoly for the Golden Rock workshops of the S. I. Railway. The Erode Municipal substation is close to the Receiving Station, which supplies power to it as also to Bhavani and Mettur by one feeder and to Salem by another. Erode and Salem Municipal substations are managed by Messrs. Octavius Steel and Co. The distances are approximately as follows :— Erode S. I. Railway 1 mile, Bhavani 10 miles, Mettur 36 miles and Salem 37 miles. The distance from Erode to Trichinopoly is 82 miles.

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At the S. I. Railway substation, 22000 volt supply is stepped down to 3300 volts by two 250 kVA transformers. The motor at the Cauvery Pumping station 2 miles away run at 3300 volts, but the five motors at the water works near the substation operate at 400 volts, which is obtained from the station transformer, 3300 delta 400 star. This transformer also enables the lights to be worked off 230 volts. The municipal substation transformers are connected thus :—22000 volts delta 6600 volts star, 215 kVA.

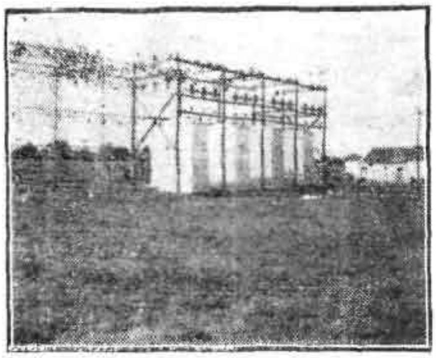


Fig. 35. Outdoor Receiving Station, ERODE.

The sub-stations, which receive power from the Receiving Station for the purpose of distributing it to nearby places, are to be of the outdoor type. Local licensees for bulk supply will receive power at 11 or 22 kilovolts. Numerous villages will certainly require power for pumping besides lighting. The cost of power will probably be one anna and three pies per kilowatt-hour; or a flat rate of one rupee per horse-power per month will be charged to those who prefer the latter. If desired, equipment will be supplied on the hire-purchase system. The effective horse-power now made available is nearly 22,000 h. p. The actual cost of the Pykara project is in the neighbourhood of one crore and twenty-six lakhs of rupees, which was the sanctioned estimate. To encourage the ryot in consuming larger quantities of electric power (to use popular phraseology) the Government will even undertake repairs of the electric appliances installed by the people in their premises. Protective devices have been provided in all the stations to ensure continuity of supply and thus inspire confidence. The annual income expected to be about 3½ lakhs of rupees has been obtained. Extension to Tanjore, Tiruvalur, Negapatam, Kumbakonam, Mayawaram and other places near these towns has been taken in hand, the estimated cost being 21 lakhs.

The following extract pertaining to Ootacamund is from Garckes' *Manual of Electrical Undertakings* :—

Ootacamund supply originally commenced 15-9-1923 at 5000V by Nilgiri Power Syndicate, by Madras Govt. H. E. Dept. in Nov. 1929 at 11000 V from Pykara P. S. 15 miles away.

System :—14 pole-type 5000 V, 3-phase transformers; 3 c. c. transformers for series street lighting; 15 miles of 5000 V, H. T. 3-phase and 25 miles L. T. aerial lines. Supply also given to Coonoor, St. George's Homes, Katery Estate and other tea estates.

Supply statistics (1932):—kWh purchased 785,650; sold 727,655. Revenue Rs. 125,432. Working costs 74,640. Interest and loan charges 67,333 rupees. Net loss Rs. 16,541. No. of consumers 669, public lamps 960, total connections 737 kW, maximum load 451 kW, load factor 19·87 %.

TABLE NO. 33 :—*Pykara Transmission Lines, particulars.*

Line	Miles	kV	Circuits	conductors	N. B.
Singara-Coimbatore	49	66/110	two	6/·028 7/·'69	1
Singara-Ootacamund	15	11/22	,,	...	2
Coimbatore-Tiruppur	30	22/66	,,	7/·144	...
Tiruppur-Erode	28	,,	,,	,,	...
Erode-Mettur	37	22	one	7/·118	3
Erode-Salem	36	,,	,,	,,	...
Erode-Trichinopoly	82	66	...	...	...
Trichinopoly-Tanjore	30	,,	...	...	...
Tanjore-Tiruvallur	30	33	...	...	...
Tiruvallur-Negapattam	14	,,	...	...	...
Tiruvallur-Mayavaram	24	...	1	...	...
Tanjore-Kumbakonam	21	33	...	...	...
Coimbatore Palghat	34	11/22	two	7/·074	4
Coimbatore-Pollachi	27	22	,,	7/·102	5
Pollachi-Iyerpadi	22	,,	one	,,	6

N. B. (1) At a distance of 29 miles from the Power station at Singara, there is a switch-structure from which a 66-kV line is taken to transformers which reduce the pressure to 11 kV to supply Mettupalaiyam and Karamadai.

From the Coimbatore Receiving station, feeders supply the municipality, the mills, Pilemedu and Uppilaipalaiyam.

(2) From the Ootacamund receiving station, feeders go out to Devershola and Camp, to Prospect, to Ooty and to Coonoor and tea estates.

(3) Off the Erode-Mettur line, a feeder branches off towards Bhavani sub-station. Other feeders near Erode feed S. I. railway and the city.

(4) Coimbatore to Palghat is double-circuit upto a point near Madukarai cement works,-en route, a branch goes to Podanur. From Madukarai, lines go to Settipalaiyam which can also be fed from the Coimbatore-Pollachi lines.

(5) From Pollachi sub-station, a feeder goes to Udumalpet, and another feeds Pollachi itself.

(6) From Iyerpadi, two 11-kV lines feed the Tea estates there.

"During the year 1935–36, 172 pumping sets aggregating 1,069 h. p. have been installed, making a total of 269 sets and 1,879 h. p. connected to the system. Over 30 villages are now supplied with electricity...........Of the 54 factories in the Pykara area, 26 are now connected to Pykara ; five have their own hydro-electric plants and the remainder are not electrified.........A cheap off-peak rate for heating has been introduced and rates for power to tea estates revised during the year....... The thermal station at Palni will be changed over to Pykara supply in 1936–37, the programme for which year is as follows :—

1. Mettur—	Completion of the power house building and all machinery and equipment under erection. 90% completion of transmission system and substations.
2. Pykara—	66 kV oil-circuit breakers replaced by 110 kV breakers. Usual extensions to distribution system undertaken.
3. Mukurti Dam—	Completion up to height giving storage of 500 million cubic feet.
4. Madura Extension—	Line serveys completed. 50% work done. Supply of power to Palni and Dharapuram expected to be given about Jan. 1937.
5. Virudunagar Extension—	Contracts let and work commenced.
6. Rasipuram Extension—	Will be completed.
7. Kotagiri Extension—	80% will be completed.

8. Papanasam and Lammasingi Hydro-electric Schemes—	Investigations completed and reports under preparation.

Besides the above, there are schemes for thermal stations for Bezwada and Vizagapatam and a Pumping scheme for Ceded Districts." (" *Indian and Eastern Engineer*," November 1936).

Fig. 33 is a map of the region, giving an outline of the Pykara River and the Glen Morgan River and showing the Weirs for the waters led from these two streams to the Forebay, as well as the inlet to the pipe supplying water from the Pykara River to the temporary Installation or Glen Morgan Power House, which supplied energy required for the constuctional appliances used for the Pykara Project Works. Besides the two sources of supply of water to the Regulating Reservoir, its two Bunds and the two pipelines to the power house are also shown. The surplus water is returned to the parent river. The proposed Pykara power house in Singara Estate has become an accomplished fact as stated at the outset of this Chapter. This illustration gives the contour lines for the entire region from which it is clear that the net vertical drop to the Power Station situated at Singara is about 3000 feet.

Fig. 37 shows the territories of the Madras Presidency and the Mysore State and indicated on this map will be found the important places from a power point of view. This map should be useful in making the reader understand the relative positions of the present as well as the proposed Hpdro-electric schemes of the Madras Presidency and of Indian States adjoining it. Trichur and Ernakulum will receive their supply of electric energy from the Pykara Power House. For facts and figures about Pykara and other Madras schemes I am indebted to the engineers and publications of Electricity Branch of Madras Government, from Major Howard downwards. Pykara and Mettur mains will linked up at Erode.

" Due mainly to the co-operation of the Coimbatore industrialists, tea-estate managers and many of the licensees, the commercial success of the Pykara scheme is now assured. Development of the Coimbatore district due to a reliable supply of cheap electricity is clear from the following :—

Textile mills in operation in 1932	8
New mills in operation since hydro-elec. power became available	10
Mills under construction	10
Mills registered	4
	32

All the above are electrically operated. Of the original mills, 7 have already changed over to hyd-elec. power and the eighth will have completely changed over by next year. In addition, a cement plant with a capacity of 50,000 tons a year, steel rolling mills at Negapatam and several small industries have been established. All licensees in Govt. Power areas have closed down their generating plants and are taking their requirements from Government. 2,000 h.p. is being used in small pumps at one anna per unit. A small house-holder or bazar shop wired up by the Dept. and one 40 W lamp is supplied at 6½ annas per week paid in advance." (Major Howard in CAPITAL, December 1936.)

Figure No. 37 shows Hydro-electric Installations in South India. The blocks for this figure and for fig. 33 were kindly supplied by the Editor, Electrotechnics, Bangalore. Several of the cities and towns named in the Chapters Nos. IV and XV to XVIII and other important adjoining towns are marked on this map. But the reader's attention is particularly directed to the Power houses, existing and proposed, indicated by small squares and the substations indicated by small circles. To the North are shown the famous generating station of Sivasamudram in the Mysore State, the Mettur Dam station and the Pykara power house. To the south are indicated the proposed plants of Palni hills and of Periyar river. Travancore and Cochin are also shown. The latter is shown connected to the Pykara network, but the former is not so shown because Travancore State is undertaking hydro-electric development on its own account, vide Chapter XVII. It is doubtful if Cochin will ever take bulk supply from the Pykara system. It may put up its own hydro-electric plant. Owing to the almost alarming rate of progress of the demand for power from the Pykara plant (from 1000 kW in April 1933 to 10,100 kW in March 1936), the Mukurti Dam Scheme was sanctioned in 1935 (at an estimated cost of 21 lakhs) to store water in the Mukurti Basin 10 miles west of Ootacamund. This has increased the energy available at Pykara by 12½ million units, by storing 1800 million cu. ft. by means of a 90 ft. high Dam. Later on, the construction of a weir or dam across the Porthimund stream will be taken in hand, if Mukurti storage can not cope with the demand. 67,000 kW could eventually be generated. Fig. 38, the block for which was kindly lent by Major H. G. Howard, Chief Engineer for Electricity, Madras, shows the large outdoor Receiving Station at Coimbatore.

CHAPTER XVI.

METTUR-DAM HYDRO-ELECTRIC PLANT.

Besides supplying electric power to several towns and villages situated within the Mysore State, the Sivasamudram Hydro-Electric Installation has been of use to the Madras Government in furnishing power required by them on a large scale for various purposes at Mettur, Salem and Erode. The gigantic Dam at Mettur undertaken in 1925 in connection with the Cauvery Mettur Project to store 93,500 million cu. ft. of water, cost 4·8 crores and required for its construction a considerable amount of power of all kinds. The variegated structures, plants and operations there have been of intense interest to civil, mechanical and electrical engineers. We shall refer here briefly to items of electrical interest only.

Electric power to the tune of 5,000 kilowatts was supplied over steel-cored aluminium conductors at the pressure of 35,000 volts from a place 63 miles away (as the crow flies) from the place where it was utilised. The frequency of the alternating current of supply was 25 cycles per second and was changed to 50 cycles per second at the Mettur Dam Receiving Station. The electric pressure of supply was first stepped down by means of transformers to 2200 volts, 25 cycles which was changed to 3300 volts 50 cycles by frequency converters, these being medium valves suitable for motors. Moreover, rotary converters, each 375 kW and giving 440 V D. C. were employed to alter the alternating current received from the Receiving Station to direct current at the Substations located on the movable Steel Towers of huge dimensions which were employed for lifting the materials of construction, for preparation of cement concrete and spraying the same over the surface of the dam. Further details are unnecessary as the Plant which was put up for a definite purpose is no longer working, since the Dam has been completed. Though the Mysore State Receiving Station and substations at the Steel Towers have become redundant with the completion in Aug. 1934 of the Cauvery Mettur Project, it will not fail to be still of interest to electrical engineers.

The feature of the Mettur or Stanley Dam which will still be of interest is the provision made in it at a cost of about 11 lakhs for the

generation of electric power from the waters stored in the vast reservoir created by the Dam. Before describing this feature, it may be mentioned in passing that the Cauvery is the same River which had been already harnessed by the State of Mysore at Krishnarajasagara for irrigation purposes and at Sivasamudram for power generation.

The Mettur Dam is 171 ft. wide at deepest foundation, 5,300 ft. long and 176 feet high above the reservoir bottom and the average discharge of the Cauvery River is 20,000 cubic feet per second during the two monsoons of the year and the minimum flow of the river is 800 cusecs. The designers of the Cauvery Mettur Project have not failed to utilise the large volume of water and good head available at the Dam. They have provided for four culverts, each 8ft. 6in. in diameter, 150′ below F. R. L., at the base of the Dam; all these culverts being lined with cast-iron flanged pipes 102 inches in diameter, the pipe-entrances being bifurcated to form eight inlets of rectangular section by means of a bell-mouth at the junction. Fig. No. 36, kindly given by the '*Times of India*', shows water rushing out of the four hydro-electric pipes of the Dam. The inlets are fitted with removable screens, each 25ft. high and 7 ft. wide which slide in grooves and are made up of mild steel bars, 3½ in. by ½ in., within a steel frame. If any screen is choked, the fact will be indicated in the power house and another screen will be lowered. At the end of each culvert, there is to be a Turbine. The water operating the turbines will be controlled by (a) a rolling gate lowered down a well, when required, from the top of the Dam at its upstream end and (b) a regulating needle-valve, 102 in. to 72 in. in diameter, provided at the down-stream end of each culvert. The work of completing this Hydro-Electric Installation was taken in hand by the Madras Govt. Elec. Dep. in the year 1935, as it had been decided to supply power to Negapatam on the East coast where a steel rolling mill is to be started shortly. Each unit of this Installation incorporated in a Dam will operate at heads varying from 60 to 160 feet depending upon the level of the Lake and produce from 5300 to 15000 h. p. The plant will ordinarily be able to furnish about 33,000 H. P. with an average head of 125 feet and 60,000 h. p. in emergency; that is to say, sufficient power for not only places like Mettur, North and South Arcot Districts to the North and Salem, Erode and Trichinopoly to the South, which are situated near the source of power, but also eventually places in the Central and Eastern parts of the Presidency, such as Madras, Chingleput, Trichinopoly and Tanjore. Madras alone can consume all the energy that the Mettur plant can send, as the existing steam plant is 34,000 kW. However, for places beyond the range

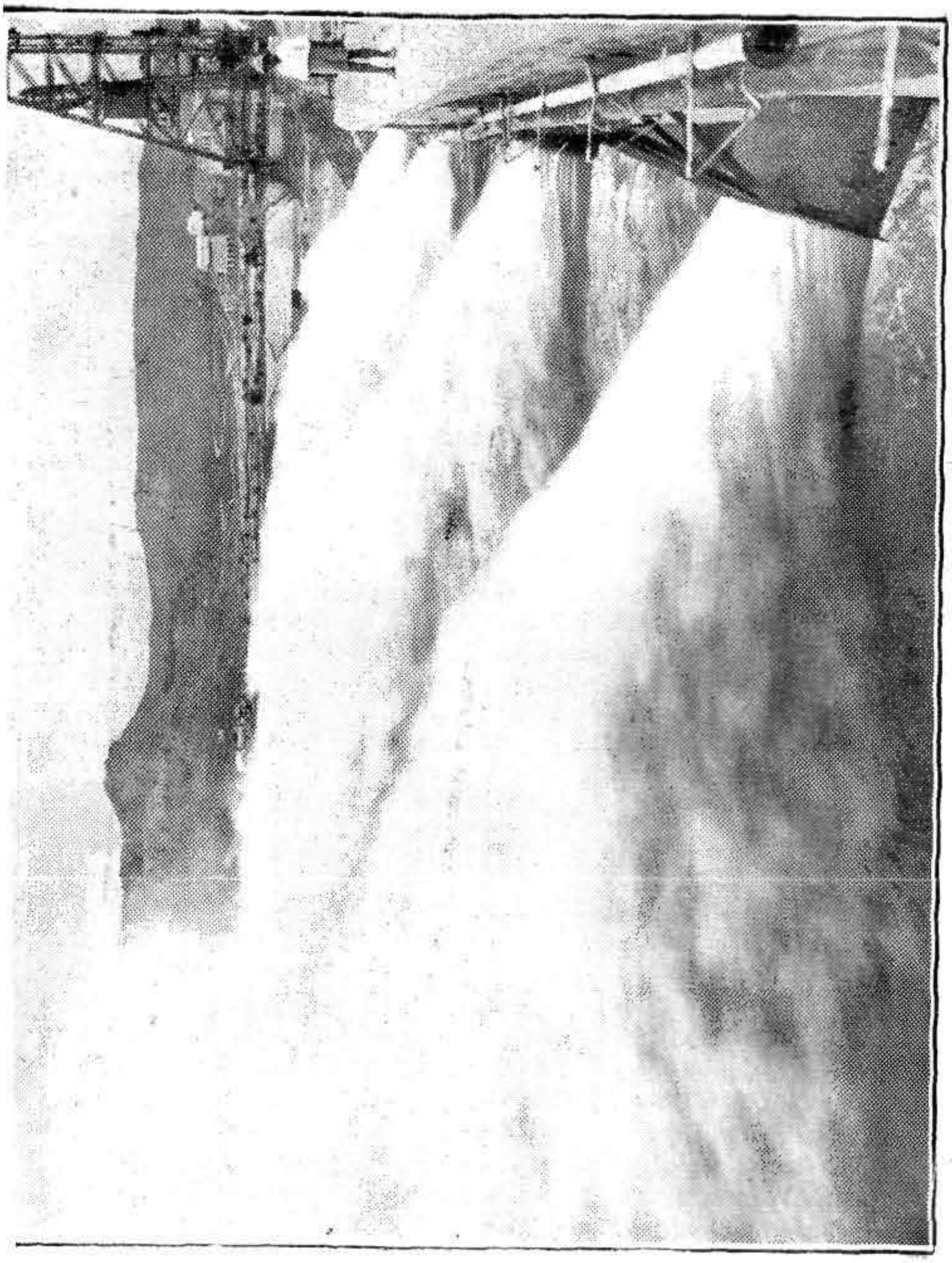


Fig. No. 36. Water Power Sluices, METTUR DAM.

of the Mettur Dam Installation, e. g. the North-Western and Southern parts of Madras and Travancore and Cochin States, supply will be made available probably from other and larger hydro-electric installations, which will be used to supply or supplement the needs of several large towns and industrial centres. The Pykara plant has already begun operating, the Power Station having been inaugurated in April 1933, and the Mettur Dam Hydro-electric Installation has also been recently completed. The Mettur Dam Hydro-electric Schemes, stations and systems are estimated to have cost approximately 180 lakhs of rupees. Other installations of South India are referred to in the two chapters following this one.

"The four turbines now being installed will be able to provide 52,000 h. p. when taking 4,110 cusecs at highest head and 10,240 h. p. with 2,560 cusecs at lowest head. The pipes are fixed at 48′ centres. The power house is a steel-framed structure with eight bays of 30′ span each, a repair and unloading bay of 36′ at one end and a switchgear bay of 35 at the other end; the building is 42′ wide. The switchgear bay has 3 floors,—the ground floor for the battery and transformers, the first floor for the control panels and the second floor for the office. The total height from floor to ceiling is 54 feet. At the eastern end, a basement annexe is provided to accommodate the Salem water supply pumps which will raise water from the tail-race to a high level reservoir. The transformer yard to the east of the powerhouse is 240 ft. long. The four 17,000 h. p. twin or double horizontal overhung Francis turbines, each unit 8,000 h. p, with runners of stainless steel operate at 250 r. p. m. under varying heads of from 60 to 160 ft. The maximum run-away speed at 160′ is 570 r. p. m. The efficiency is about 70 p. c. at ½ load, 89 p. c. at ⅞ load and 83·5 p. c. at full load. Of the four units, one will be a standby. At present, 3 units are installed, each 12,500 KVA,—velocity of water being 22 f. p. s. in the 8½′ pipe, at full load. The station will operate in parallel with Pykara station and Madras Steam Station. Ultimately, Mettur station will send power to Madras. Three H. T. lines will go out; one to the east towards Madras, one south-west towards Erode and one to Moyar, the last being not required till the second stage. To begin with, a double-circuit 110 kV line will go 63·5 miles to Singarrappet (originally at 66 kV) to supply a single circuit 66 kV line (69·5 miles) proceeding thence to Vellore and another line will go to South Arcot. Other 66 kV lines will go to Trichinopoly and Negapatam *via* Erode, 36 miles from Mettur. The generators are each 12,500 KVA 3 phase 50 cycle 11 kV, tied to a single bus through oil circuit breakers. Step up Transformers are connected to duplicate H. T. busses through oil circuit breakers and

selector disconnecting switches. The H. T. bus has 2 sections, one 66 kV for southern area and one 110 kV for Madras and Moyar. The 3 outdoor transformers are each 17,500 kVA units with double-ratio H. T. windings. There is an auxiliary 11 kV bus for 2 station transformers, each 250 kVA, stepping down voltage to 400 V. There is a 400 h. p. 400 volt station service turbine set for emergency use and a 200 amp—hr 110 V storage battery. An area of 25,000 sq. miles with a population of 12 million will be supplied." (*Indian and Eastern Engineer*, May and June 1936).

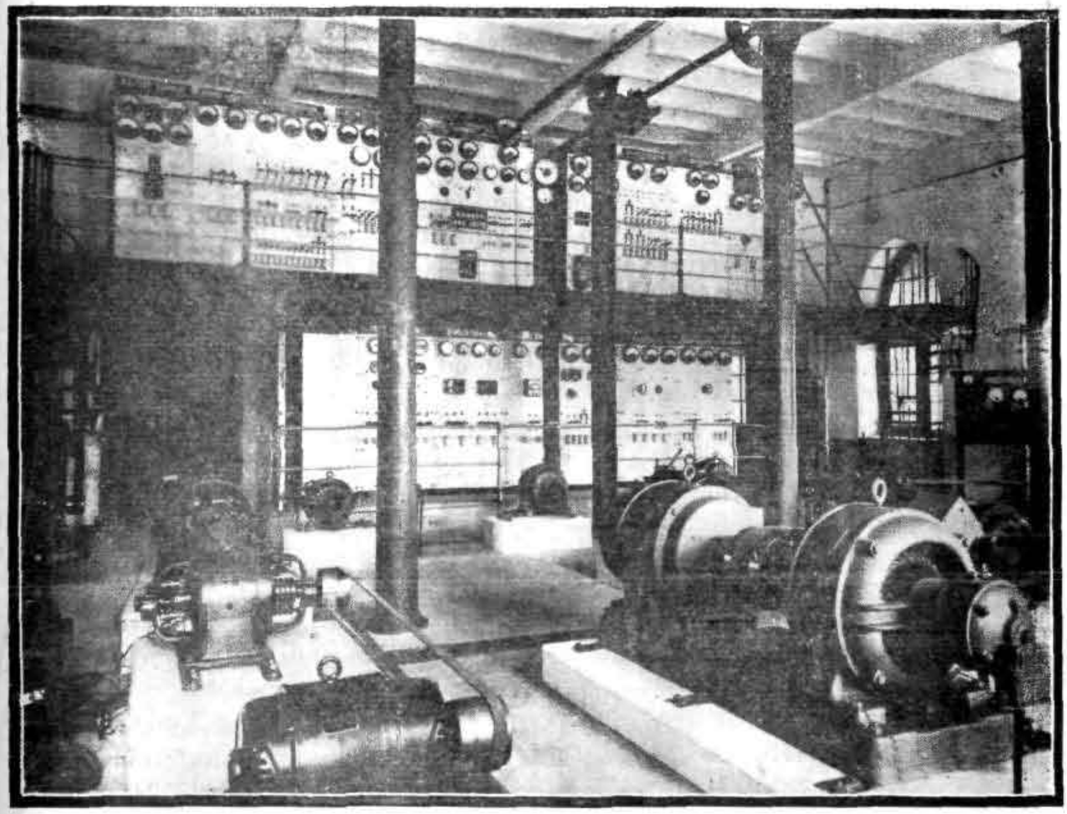


Fig. 36 (a) Machines and Switchboards, Dynamo Room,
THE AUTHOR'S LABORATORY, COLLEGE OF ENGINEERING, POONA.

CHAPTER XVII.

TRAVANCORE STATE WATER POWER PLANTS.

I. The Periyar Installation being close to the frontier of the State of Travancore was expected to supply some power to the latter, just as Cochin State was expected to take its supply of electrical energy from the Pykara plant. But the Travancore State which was ambitious of possessing a Water Power Installation of its own has undertaken to harness in the near future the waters of the Munnar River near Pallivassal on the Western Ghats. The Pallivassal Hydro-electric Scheme of Travancore State has already been sanctioned by the authorities concerned and works of construction commenced in earnest during 1934–35. In its two stages, it is estimated to cost altogether about Rs. 71 lakhs. Cochin State may follow suit and start its hydro-electric scheme. Electric power will first be supplied to the tea estates which already own their separate electric stations in the Devicolam area and to places round about Pallivassal water-fall and neighbouring streams. The River (Mudripuzha) of which the water falls here, is a tributary of the Periyar which it joins below Munnar, where an installation already exists. Pallivassal station will for the present, have two 2,500 kVA transformers and 95 miles of 66 kV lines will issue from it but power will eventually be transmitted to places farther away, such as Kottayam, Allepey, Alwaye, Changanacherry and other areas. It is believed that when electricity supply is rendered available, it will be utilised not only for illumination and industrial purposes but also for pumping for water supply and irrigation. A definite load of 7 to 8 million units per annum is assured from the outset.

The following extract from the *Times of India* relates to the Pallivassal Hydro-electric Scheme :—(' The Pallivassal waterfall is at Munnar on the Mudripusha River, tributary of the Periyar, 4750 ft. above sea-level ')

"The water from the Munnar river will be diverted and led through a cut-and-covered-channel to a tunnel (through the Ghat) about 10,000 ft. long, having a gradient of 1 in 350 and a finished section of approximately 9′ × 8′. From tunnel-exit, water will pass through an open channel to a stilling pond and decantation chamber and thence to a Forebay (4,715′ above sea-level) which is designed as a spillway tank. Two penstocks (each 7446 ft. long) take off from the forebay,

each of them designed to carry 30 cusecs. Each penstock will feed one generating set of 5,000 kVA. There will be three such sets, one serving as a stand-by. The corner stone of the generating station 2,760 ft, above sea-level was laid on Mar. 1, 1935. The head will be about 1,880 ft. Transmission lines will be taken over the hills to the first tapping station at Kothamangalam, 31 miles from Pallivassal. There will be two circuits on towers of an average span of 6 to a mile. From Kothamangalam, one line will be carried on to Alwaye (and another line to Pallam). The main 66 kV line will go from Kothamangalam via Pallaw to Kottayam, a further distance of 43 miles. The main receiving station will step down to 33 kV at which pressure power will be taken to Allepey to be lowered to 11 kV for local distribution. At Kottayam, power will be distributed at 11 kV to Kottayam town, Changacheri and Thiruvella. From Kottayam receiving station, another 66 kV line will be taken to Peermade for the planting area. The total output of 10,000 kVA shall be developed without storage of water. The tunnel is scheduled to be completed in 26 months." "The Pallivassal project (initial capacity, 9000 kW) is expected to be in operation next year."–*Capital*, Dec. 1936. For further expansion, storage sites are available. The present tunnel is designed to handle about 30,000 kVA. For details, reference may be made to Volkart Engineering News, March 1936.

On the Tambrapani river, in the State of Travancore, there are 'falls of 1200 ft. in $1\frac{1}{4}$ mile with a very small catchment (about $3\frac{1}{2}$ sq. miles) in the hills near Ambasamudrum'. (T. R. W. P. R.)

II. A short account, based on Mr. Cole's article in *Distribution* for June 1932, will now be given of the Munnar Installation, to which a passing reference is made on page 187 of *Hydro-Electric Installations of India.* The Munnar Valley Installation was one of the earliest hydro-electric installations of India having been inaugurated in 1906, by a big tea company, on the right bank of the Munnar river, at a spot where the effective head is 700 feet. The supply channel is three-quarters of a mile long and the length of the pipe-line is 248 feet only. Two generating units are installed, each consisting of a Pelton Wheel of 585 H. P. coupled to an English Electric alternator of 2200 volts and 500 kilovolt-amperes. The two old units of 150 K. W. each (in the Left Bank Station for which the head is 380 ft.) will serve as a standby plant for use during heavy tea flushing period, when the load is beyond the capacity of the principal units. Transmission is at 11,000 volts and upto a distance of 22 miles. There are 24 factories with an area of 21,000 acres under tea. About two-thirds of a kilowatt is required to fire or dry one pound of tea.

The generation cost of electrical energy comes to about one and a half anna per Board of Trade Unit or Kilowatt-hour.

The following information about Hydro-electric Installations in the Annamallais District has been kindly furnished by the Chief Engineer of the Kanan Devan Hills Produce Co. Ltd., Munnar, Travancore. The notes in brackets are from Garckes' Manual of Electrical Undertakings, 1933-34:—

(1) *Annally* Power House was erected in 1915 and consists of two English Electric Alternators of 70 kW. each coupled to Gilbert Gilkes and Gordon Pelton Wheels. The head on this scheme is 700 feet and the station is used entirely for the supply of energy to two Tea Factories and a Workshop. The transmission system exceeds six miles of 2200 volts transmission, three phase, 50 cycles, at which voltage the alternators operate. Owned and operated by the Anglo-American Direct Tea Trading Co. Ltd. (Hill stream, minimum flow 3½ cusecs, open-channel 300 feet, pipe-line 3000 ft., capacity for full development 180 kw.)

(2) *Koltagudi* Power House was first erected in 1900 or about that date when a 500 volt D. C. Plant was installed. This original plant was replaced in 1912-13 with more up-to-date D. C. sets of Dick Kerr manufacture. The Pelton wheels were of Gunther manufacture, operating on 700 ft. head. This plant was again replaced with 440-volt A. C. 3 phase plant in 1932 and the alternator is 100-kVA capacity coupled to 126 B. H. P. Gilbert Gilkes and Gordon Pelton Wheel operating on 700 ft. head. The voltage is stepped up to 2200 volts for overhead transmission and supply of energy to an aerial ropeway of 2½ miles in length. The power requirements of this ropeway being 70 H. P. under full load conditions. Owned and operated by the Kanan Devan Hills Produce Co. Ltd. (Plant at Bodinayakamer, Madura. Hill stream, minimum flow 3½ cusecs, open channel ½ mile, pipe-line 1780 ft., capacity for full development 160 kW.)

(3) *Pannimade* Power House was constructed in the same district in 1923-24 and consists of two 50-kW. sets coupled to Gilbert Gilkes and Gordon Francis Turbines operating on 70-ft. head. This station is also supplying two tea factories. The transmission system consists of about 5 miles of 3-phase 50-cycle 2200-volt distribution at which voltage the sets operate. Owned and operated by the Amalgamated Tea Estates Co. Ltd.

The Cochin State is expected to replace its thermal stations at Trichur (600 kW) and Ernakulum (800 kW) by a hydro-electric installation at Poringalkuttu.

CHAPTER XVIII

OTHER WATER POWER PROJECTS OF SOUTH INDIA.

After the completion of the Hydro-electric system emanating from the Dam at Mettur, the Trichinopoly and Tanjore load will be switched on to it and the Pykara system will be extended to supply Madura District. Then, the Madras Government will perhaps take in hand the construction of the Periyar Water Power Project, sometime in 1937–38. It is therefore expected that the preliminary work of preparing plans of beginning the work of construction will start very soon. Periyar is near Kodaikanal Road between Madura and Dindigul. The Periyar Scheme is estimated to cost 20 lakhs less than 2 Crores of rupees (Rs. 180,000) and judging from reports in the Press, the financial condition of the Presidency is now such that there should be no difficulty in providing the necessary funds, particularly as the Project promises to be an investment of such a nature as is likely to bring in a good profit and to increase the revenues of the Madras Government, besides conferring many benefits upon the people of the Presidency. It is even possible that the actual expenditure may be less than that estimated, owing to a fall in the prices and owing to the fact that the plant and personnel already employed in the previous water power projects of the Presidency will prove efficient as well as economical if re-employed for the construction of the Periyar Works, as they have been tried and trained and found satisfactory. Surveys of H. T. transmission lines extending over 400 miles and other preliminary works have been completed.

Fig. 37 shows among other places, the relative location of the Periyar and other Power Houses. The lines radiating from it show that the Periyar Power House will be primarily used to provide electric power required at Madura, Trichinopoly and other places of industrial importance in the South of the Presidency. Eventually there would be formed a "Grid" or ring-main of the various Transmission Systems of the Presidency, one station helping the other in emergency or even normally by sharing the loads of industrial centres and large towns situated along the border-lines of the two systems and thus making supply from both sources more stable and more

secure against the incidence of internal and external causes of interruption or break-down of any one of the several links of the chain in either system. On completion of the Periyar scheme, it will take over the Madura load from the Pykara system.

The waters of the Periyar Lake which is situated in the Madura District will be conveyed through a tunnel, which is yet to be constructed, to a hydro-electric power station calculated to develop 15,000 kilowatts of electric power.

It is proposed to harness the Tungabhadra River at a site in the Bellary District. The project concerns the Governments of Madras, Mysore and Hyderabad and is awaiting sanction.

Besides the Glen Morgan and Pykara plants, a small hydro-electric station exists in the Nilgiri Hills at Karteri Falls to supply power required by the Cordite Factory at Aravankadu (see "*Hydro-Electric Installations of India,*" pages 166 and 167 for a detailed description of this comparatively tiny station where oxide film or Thyrite Lightning Arresters have been installed out of doors. Fig. 57, H. E. I. I. shows diagrammatically a lay-out corresponding to that of the Karteri Falls Development. Lightning arresters and choke coils on the line as well as near busbars are installed.

A few words regarding the other Power Stations indicated on Fig. 37 will now be quoted from the Reports on Water Power Resources. "Hydro-Electric Survey of India—Madras Sites. *The Papanasam Falls*, 22 miles from Tinnevelly and 54 miles from Tuticorin are 250 feet high. The river is already utilised by Messrs. Harvey Bros. for their mills at Ambasamudram (P. R. W. P. R., Page 92). *Palni Hills.* Three schemes are mentioned in the Triennial Report on the Water Power Resources of India, page 141 *et seq.* (1) *Pinjikave Project, Koniar River, Madura District.* There is a clear fall of 5,000 feet in a few miles. It is proposed to be taken in two stages developing 2,700 kilowatts in each stage. (2) *Palni Hills, Porandalur River.* The fall here is 1500 feet and the power expected 1500 kilowatts continuous. (3) *Palni Hills, Kumbar River.* A fall and output equivalent to Scheme No. 2 is estimated". The Papanasam scheme will be a combined irrigation and hydro-electric project and is estimated to cost about 30 lakhs. A small hydro-electric installation may be put up at Chettipet for the purpose of pumping.

TABLE NO. 34.

Maximum output in horse-power possible from sources of hydro-electric power in Madras Presidency.

Pykara, Nilgiris	...	100,000 h. p.
Kolab, Viziagapatam	...	70,000 „
Machkand, „	...	70,000 „
Periyar, Madura	...	55,000 „
Mettur, Salem-Coimbatore	...	45,000 „
Papanasam, Tinnevelly	...	40,000 „
Cholatipuzha, Nilgiris	...	40,000 „
Silent Valleys „	...	30,000 „
Kumbar, Madura	...	30,000 „
Pinjikave, „	...	20,000 „
Thalipuzha, Malabar	...	10,000 „
Chettipet & Canal falls, Godavari	...	1,000 „
		511,000 „

N. B.—This information has been taken from a report of Mr. Sundaram's paper published in a Bombay daily.

TABLE NO. 35.

" *Units of Electricity generated in the Madras Presidency, during the past six years.*

Government	1929-30	1935-36
Hydro	...	50,281,862
Oil	...	773,833
Municipal Councils		
Oil	928,621	4,696,765
Companies		
Steam	24,496,160	43,143,966
Oil	965,872	5,633,025
	26,390,653	104,529,451

The number of licensed undertakings has increased from 19 in 1929 to 50 during the year under review. The Madras Govt. is now the largest single producer of electric power". Major Howard, in CAPITAL for December 1936.

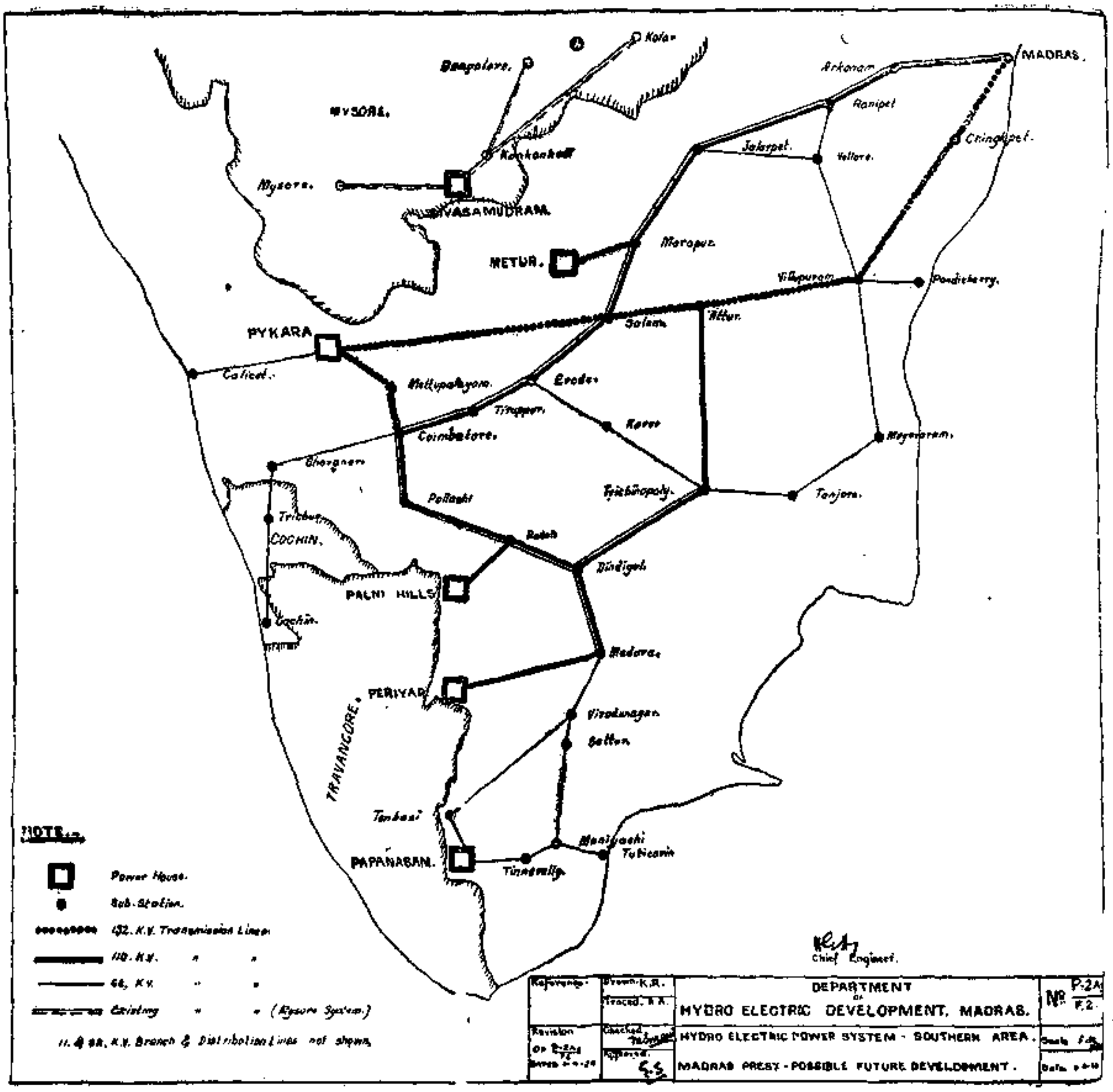


Fig. No. 37. Water Power Development Map, **Mysore and Madras.**

CHAPTER XIX.

WATER POWER PROJECTS OF BURMA.

In Table 45 on page 245 of 'Hydro-electric Installations of India,' mention of sites for hydro-electric survey and reconnaissance in Burma will be found. The Maymyo Scheme which was completed in 1933 is described in the following extract from the *Times of India*:—

"The possibility of the Maymyo Hydro-electric Scheme was conceived in 1927 and an application for the grant of a license was submitted in 1928. The successful completion of the scheme which will be an asset of public utility to the town of Maymyo, and to the town of Mandalay to which it may be extended in future, is an achievement from the point of view of the company. The company's attention was first directed to the harnessing of a fall of about 230 feet.... After a prolonged survey of the adjoining land of the upper reaches of the Gelaung Chaung river and its tributaries, it appeared possible to contrive a method of connecting hill-tops thus enabling an open channel system to carry the maximum quantity of water to the height of 800 ft. above the bed level of the Chaung, immediately below the 230 ft. fall.

The pipe-line is 1000 ft. long and the difference in level between the forebay and the turbine is 700 ft. It has 8 bends and the steepest slope on the last section is nearly 41 degrees. The turbine is a single-runner Pelton wheel with two jets and is provided with an automatic oil-pressure governor for controlling the speed. It is designed to run at 1000 r. p. m. and for a maximum output of 370 b.h. p. It was manufactured by Messrs. Boving and Co. at their works at Kristinehamn.

The turbine is direct-coupled to a 3 phase 50 cycle A. C. generator delivering 280 kVA. at 420 volts. The generator is solidly connected to a 280 kVA oil-immersed self-cooled 11000 volt transformer. An interesting feature of the transformer is that not only the end turns of the high-tension windings are provided with specially reinforced insulation as is generally the case but the whole of these windings are insulated to such an extent whereby external lightning arresting gear for the protection of the windings is not necessary. The generator-transformer unit is provided with switching arrangements on the high-tension side only. The switchboard comprises in

the present stage only one panel with an oil switch, a potential transformer and necessary disconnecting links mounted in a high-tension section. A separate low-tension section is provided for the exciter control apparatus, instruments, protective relays etc.

The high-tension voltage is automatically controlled by an Asea high-speed voltage regulator–provided with a device for automatic compensation of the voltage drop in the transmission line so that the substation voltage is kept constant at all loads.... In order to protect the generator and transformer windings in case of internal faults, the over-current relays are connected to current transformers arranged on the neutral side of the generator, and the exciter is provided with an automatic field switch which trips simultaneously with the high-tension switch. In addition, acoustic signalling is arranged to operate in the case of earth currents on both the L. T. and H. T. sides, combined with time-lag releases of the oil switch in the latter case. Over-voltage release is arranged to safeguard against over-voltages occurring at times when the voltage regulator is not employed. The H. T. transmission line is about 13½ miles long. A private telephone system has been put up connecting the Power station with the town office and the substation. The instruments and cables were supplied by Messrs. Ferranti Ltd. and Messrs. Callenders Cable and Construction Co. Ltd. respectively. The entire electrical equipment was manufactured by Messrs. Asea Electric Ltd. at their works at Vesteras, Sweden and Walthamstow, England."

Burma, being rich in oil, may not feel the necessity of harnessing its water power resources in situations where electrical energy could be produced cheaply by using oil engines.

II. HYDRO-ELECTRIC POWER PLANTS OF THE BURMA CORPORATION, LIMITED.

"The Burma Corporation Ltd. owns and operates two hydro-electric power plants which utilise the waters of the Namyao River. One is situated at the Mansam Falls and operates under a head of 250 ft. whereas the other station is built at the Konnyaung Falls where a head of 150 ft. is available. There is a distance of about 5 miles between the two stations. There are no dams or storage reservoirs incorporated in the scheme and at times when the flow of water in the river is low, practically all the water available flows through the turbines. Owing to the seasonal nature of the rainfall in the Northern Shan States, the flow of water in the Namyao River varies considerably from a flood condition during the monsoon period to a relatively limited flow in the dry season. This

variable position is further influenced by the fact that there are wide stretches of Paddy land along the valley of the Namyao river and, consequently at times, a considerable quantity of water is withdrawn from the river for rice cultivation purposes. During the periods of ample water supply, the whole of the load of the Burma Corporation's Mine, Mill and Smelter is carried by the Mansam Falls Power Station. When, however, the flow of water in the river is insufficient to generate the full requirements, the Konnyaung station is brought into commission to augment the power available from Mansam. In each of these power plants, the generating station is built near the foot of the falls. A concrete-lined flume conveys the water from above the falls to a forebay, conveniently situated with respect to the power station, and from this forebay steel penstocks convey the water to the turbines. The water turbines are of the horizontal-shaft Francis type manufactured by Messrs. Boving and Co. Ltd. of London. Each turbine is directly coupled to a 3-phase 50-cycle, 3300-volt generator with direct-coupled exciter but, in the Mansam station, a separate Pelton-wheel-driven exciter is available for emergency purposes. The generator voltage is automatically controlled by Tirrill voltage regulators which keep the busbar voltage steady within very close limits. Oil-insulated step-up transformers in each station raise the voltage to 33,000 volts, at which pressure the power is transmitted to the Mine at Bawdwin and to the Mill and Smelter at Namtu. The switchgear which controls the various circuits is of the remote-controlled type. The numbers and sizes of the various generating units and transformers are as follows :—

Mansam Falls Station —3 generators, each 2500 kVA ; 1 generator, 5000 kVA; 3 banks of transformers, each 3600 kVA.

Konnyaung Falls Station—1 generator, 2500 kVA ; 2 banks of transformers, each 2550 kVA."

N. B. The above description was kindly furnished by the Secretary, Burma Corporation Ltd. to whom thanks are due. The years, during which the two stations were put up, are not mentioned in his letter.

III. HYDRO-ELECTRIC PLANT, HEINDA MINE, TAVOY DISTRICT.

This plant belongs to the Anglo Burma Tin Co., Ltd. whose General Manager has kindly furnished the following information about this small plant which was installed in 1934.

"The main water supply, brought in from a reservoir formed by a reinforced-concrete dam 30 ft. high and 155 ft. wide at the crest (measured along the curve of true segmental design with radius of 66 ft.), is led to the Mine in 33″, 29″ and 26″ slip-jointed pipes, a distance of 2 miles. The static head is 425 ft. Only about 25 p. c. of the water is converted into electrical power, at a suitable point where the pipeline reaches the flats. The remaining 75 p. c. is used for direct use in Pelton wheels driving gravel pumps by belt drives in hydraulic elevators and in monitors. A portion is carried to a point slightly lower than the dam-intake, and the hydro-electric power is used for pumping this water to tin-bearing ground at a higher elevation than the dam. This pumping is however done by oil engine in the dry season.

This hydro-electric plant consists of a Gilbert Gilkes and Gordon 400 h. p. Turgo—Impulse wheel direct-coupled to a 440–volt 3–phase 50–cycle generator of Messrs. Crompton Parkinson and Co. Ltd. The effective head is 350 ft. and the wheel is governed by the shaft pendulum type of governor. A step-up transformer raises the voltage to 6600. The present transmission line is approximately 1½ miles, but will be extended later. The main motors are 440 volts, to which the line voltage is stepped down at the pump house. These consist of one 135 h. p. Crompton induction motor direct-coupled to a 2–stage centrifugal Gwynne pump operating against a head of 350 ft., and a 125 h. p. Crompton synchronous motor driving a single stage Pulsometer centrifugal Gwynne pump operating against a head of 200 ft. The latter is being replaced by a 4–cell turbine pump to operate against a head of 450 ft. Subsidiary small pumps etc. are also electrically driven. On the flats, all lighting is done by a 8 kW Pelton driven lighting set, with servomotor governor."

J. E. Robbins in his "Hydro-electric Development in the British Empire" refers to the Yunzalin Diversion Scheme of 1923 and a site within reach of Rangoon, situated some 125 miles from the town, which would provide probably 150,000 b. h. p.,—further records of rainfall are being collected. The water-power resources of Burma amount to 953,000 kW, vide World Power Conference 1924, Vol. I pp. 449–459. This figure is highest for any Indian province; next to Burma, comes the Punjab with 801, 900 kW and then, Bombay Presidency with 750,000 kW.

CHAPTER XX.

INDIAN WATER POWER PROJECTS.-SUPPLEMENTARY NOTES.

In connection with the equipment installed at the generating stations, formerly all appliances and machines used to be housed under the same roof. Of recent years, there is a marked tendency towards decentralisation;—either separate buildings are provided for the generating plant and its accessories, for the high-tension transformers and for the lightning arresters; or the latter are so designed as to be able to withstand the inclemencies of the weather and are installed out-of-doors. Substations are now-a-days largely installed thus and not with roofs over their heads, but batteries, rotating machines, switchboards, testing appliances and apparatus of a similar nature are housed indoors. Smaller appliances or transformers are in some places fitted up in pillars or kiosks of reinforced concrete or of sheet iron.

For medium heads, Francis or reaction turbines and for low heads, Kaplan or propeller turbines are now often preferred to other types.

Arrangements are usually made for earthing or grounding in order to avoid interruption of supply and damage to machinery. The neutrals of generators are so connected to switches that only one at a time can be earthed. Usually a resistance or reactance is inserted in the path to earth. Choke coils are used to protect against circulating currents or / and lightning. Over-current and over-voltage relays are also commonly employed. Recent plants have all adopted the standard British frequency of 50 cycles per second and frequency changer sets are therefore not installed in substations.

In connection with the transmission of power, the early plants had transmission lines taken out to a few large centres where switching stations were provided to enable separate or subsidiary concerns to buy the supply in bulk and then make their own arrangements for local distribution of power. Recently, the electrical departments of

Provincial Governments have themselves undertaken to put up all the lines and stations for transmission as well as for distribution and larger areas are covered by distribution networks under the care of the same agency that erected and looks after the whole installation. More men are thus employed under Governments as electrical engineers and their assistants. Bulk supply buyers are few and far between and usually they cater for consumers of comparatively small quanta of electrical energy. Because of this, the initial aggregate cost per kilowatt is greater as seen from the subjoined Table, but the benefits of electricity are brought to the doors of distant consumers and the foundation is laid for the establishment of industries by making the raw product of power readily available in the vicinity of suitable sites.

TABLE NO. 37.

Cost per killowatt installed, Indian water power plants.

Project	Cost (approx.), Rs.	Kilowatts	Cost per kW, Rs.
Darjeeling	4,80,420	650	739
Cauvery Falls	285,00,000	37,500	760
Tata Power Trio	1560,00,000	1,83,500	850
Pykara	150,00,000	18,750	800
Pallivassal	71,00,000	8,500	835
Mettur Dam	180,00,000	20,000	900
Periyar	180,00,000	15,000	1,200
Mandi or Uhl R.	645,00,000	48,000	1,344
Ganges canal	138,56,070 including lines	8,850	1,515

N. B.—The cost appears to be less in the case of plants in South India than of those in North India. Costs per kW for other installations will be found in Table 52 of H. E. I. I., but there, costs of hydraulic development only are considered. The cost per kW second stage of Uhl. R. scheme would be about 900 rupees, after third stage Rs. 700.

Another matter of general interest in connection with development of water power in this country is the question of freight. This item is of considerable importance as several suitable sites are far removed from railway stations and slow-moving animals e. g. bullocks and sometimes even elephants have sometimes to be used for the transportation of plant, vide H. E. I. I. page 137. On the other hand, instances exist of cases where fast-moving conveyances are used in Western countries, including among such conveyances aeroplanes. The G. E. Review for Sept. 1934 gives one such instance, quoted below :—" Four horizontal water-wheel generators rated at 875 kVA each together with associated apparatus left San Francisco (California) aboard the S. S. Carrisso bound for Lae on the coast of West Guinea, where the equipment was loaded, one section at a time, into huge all-metal Junker freight planes and *flown* 40 miles inland to the headwaters of the Bulolo R. where Bulolo Gold Dredging Ltd. has established a thriving placer mining camp."

The following notes pertaining to water power in India in particular and to electrical development in general are from "Hydro-electric Development in the British Empire" by J. E. Robbins :—

" The total power from all sources in use in India is now (1931) somewhat more than 1,000,000 kW. Roughly, one-third of this is from water power. Total Installations represents 3 watts per capita, water power therefore representing one watt per capita (which is easily remembered). In Canada, the corresponding figure was 450 W per capita in 1929......All water-power undertakings in India supply power cheaper than any fuel-operated station there. Over 70 p. c. of the people are engaged in agriculture and pastoral pursuits. Therefore power is mainly required for irrigation. Heat for drying tea could well be provided electrically. This points to a much more general use of hydro-electricity in tea-estates. Mining and metallurgy offer an outlet for the power but the electrical furnace has not hitherto been employed." (There is an electric furnace in use at the Calcutta works of the Electric Steel Co.-S. N.)

Extract from " The Times of India " for March 5, 1937 :—

(1)..." the following figures from the Balance Sheet of the Tata Power Co. for the year 1935-36—assuming power at the consumer's terminals :—

TABLE No. 38.

Tata Power Co. Costs.

Total amount spent as Fixed Capital Expenditure: that is to say, for the power plant and the transmission lines	Rs. 695 lakhs
Total units sold during the year	„ 2,123 lakhs
Operation charges	Rs. 9,51,325
Administration and general charges	„ 1,13,765
Depreciation	„ 12,04,000
	Rs. 22,69,090
Add only 5 p. c. interest on 695 lakhs, capital expenditure	Rs. 34,75,000
Total ...	Rs. 57,44,090

The above figures show that the cost per unit is nearly 5 pies.

(2) Fresh Sources of Power for Darjeeling.

"The need for fresh sources of electricity arose out of the shortage of water at the Darjeeling Municipality's existing power house at Sidrapong in the spring months. The present generating station built in 1897 has increased its output from its original 130 kilowatts to its present capacity of nearly 1,000 kW. A sum of Rs. 4 lakhs has been spent on modernising its machinery of recent years and all the available water sources for Sidrapong have been tapped but the demand still exceeds the supply. In the dry months, the Municipality has to resort to reducing the pressure and it can not extend its lines.

The possibilities of the Ramman valley were accordingly explored actually for the first time some years ago. The matter was however dropped because, the capacity of Sidrapong was not then exorbitantly taxed and because, apparently, of the complications envisaged in any proposal to tap a boundary river... It was in November 1936 that the site was again explored......a fresh survey was begun and is still in progress......the Governments of India and Sikkim share equally, it will be probably established, the water rights of the Ramman river...... Geographically, the site offers possibilities for the generation of electricity on an almost unprecedented scale. The Ramman reaches tropical altitude after about its first 12 miles' run. The first big tributary of the Ramman is the Lodhama river, and farther down the Great Rungeat river, by which name it is thereafter known. The Ramman flowing west to east is the boundary between Darjeeling and Sikkim. The site is in the vicinity of Lodhama bazar, at which point the Ramman descends 1000 feet for every mile of its length.

Nothing has been said in this book about Water Power Projects of Bihar. The interested reader will find a note about this subject in H. E. I. I. page 245. In addition to the sites mentioned therein, T. R. W. P. R. page 115 refers to (1) Dumragargi and Gilling Silling, Ranchi District, near Johna, B. N. R., 6,600 kW; (2) Koel, South, near Nagpeni, 3,300 kW; and (3) Mahanadi River, Daspala State, 10,000 kW. The Patna correspondent of the 'Bombay Chronicle' of March 16, 1937 says that "the possibilities of introduction of rural electrification in Bihar for irrigational and industrial purposes have been brought within the range of practical proposition by the public-spirited offer of the Rohtas Sugar Mills at Dehri-on-Sone to supply power at almost the same cost as available in the United Provinces under the latter's hydel scheme, from the new power stations they are setting up for their paper and cement factories ...... Working on *U. P. basis, it is expected that the cost of irrigation from the proposed* tubewells should not exceed Rs. 12 per acre for sugarcane, Rs. 3 per acre for wheat and Rs. 6 per acre for potatoes. It is believed that the entire scheme is engaging the attention of Government."

The Mysore correspondent of the "Times of India" of March 26, 1937 says that "the administration report of the Mysore Electrical Dept. for the year 1935–36 records good progress made in the State in regard to the scheme of electrification of rural areas. With a view to popularising the use of electric power, the Govt. of Mysore sanctioned the reduction of the minimum payable on irrigation pumping installations from Re. 1 per h. p. per mensem to 8 as. per h. p. per mensem and the revision of rates chargeable to industrial concerns. At the end of the year under review, there were 3,472 power installations and 27,718 lighting installations as against 3,123 and 25,184 respectively at the end of the previous year. The total power generated during the year in kilowatt-hours was 20,83,32,440 against 20,07,54,040 in the previous year. The average cost per unit of energy generated was 1.157 of a pie as against 1.187. 300 transformers of various capacities were manufactured in addition to 6 auto-transformers of 75 kVA required for stepping up voltage from 2,300 to 4,600 volts. 12 transformers of multiwound type were constructed for the Central College and the Indian Institute of Science for wireless purposes. The collection amounted to Rs. 58,51,756 showing an increase of Rs. 73,756 over the revised estimate. The working expenses amounted to Rs. 12,55,942. The net revenue for the year was Rs. 39,65,259: the capital outlay was Rs. 11,31,654. The electrification of Shimoga, Tarikere, Chikmagalur, Hassan and Hole Narsipur towns was taken up. The total cost to the end of the year was Rs. 316·57 lakhs on hydro-electric works, inclusive of outlay on telephones."

In the same issue of the same newspaper, Mr. M. V. Pant Vaidya writes as follows regarding comparative costs of power purchased from Hydro-electric companies and power generated by the Bombay mills themselves (1650 kVA set).

"Assumptions for the basis of calculations:—Cost of plant, completely erected Rs. 2,75,000: working days per year, 310; coal, 11,500 B. Th. U. per lb. at Rs. 15 per ton. Average boiler efficiency, 76 to 78 p. c. and so, corresponding evaporation per lb. of coal, 7 lbs. of water.

Annual costs including process steam:—

			Rs.
Coal, including banking fire, wastage, short weight etc. 4500 tons.			67,500
Labour	...	...	11,160
Water bill	...	...	4,000
Lubricating oil, waste etc.	...	...	3,000
Repairs, 2 p. c. of capital costs	...	...	5,500
Interest and depreciation, 10 p. c. of investment.			27,500
		Total Rs.	1,18,660

(20 p. c. increase likely would make the total Rs. 1,32,160).

Now for the costs of power purchased at the present schedule of the Hydro-electric companies and for raising the necessary steam for process work:—

Assumptions made.—Steam required per day, 58,000 lbs. at 40 lbs. pressure and 428 deg. F.; working days per year, 310; coal, 11,500 B. Th. U. per lb., therefore water evaporated per lb. of coal, 7.6 lbs., making allowance for lower inlet temperature and lower heat content; Maximum demand, 1,026 kW minus 40 for turbine auxiliaries plus 15 for transformer losses, say 1,000 kW at unity power factor or 1,050 kVA at 0.95 power factor; Two 1100 kVA transformers and 500 KVA power factor improving apparatus (to improve p. f. from 0.64 to 0.95 as in Test data) Rs. 44,000: daily consumption 8,930 plus 1.5 p. c. for transformer losses equals 9,065 units per working day; boiler make up—6,000 gallons per day. Therefore Annual costs for purchased power including process steam:—

		Rs.
Fixed costs for 1050 kVA demand		30,900
Energy charges		54,700
	Total Rs.	85,600
Less 2 p. c. for prompt payment		1,712
	Total carried over	83,888
Coal for process steam-1060 plus 120 for banking etc., 1180 tons at Rs. 15 per ton.		17,700
Water bills.		1,500
Wages, Rs. 300 per month		3,600
Other materials		500
Interest and depreciation on Rs. 1,00,000 for extra plant.		10,000
	Total Rs.	1,17,188

Note; with 20 p. c. rise in coal price, this total will go up to Rs. 1,20,740 as against Rs. 1,32,160 in the first case. So far as Bombay is concerned, the balance is in favour of purchased power even at the present rates for coal and labour which are the lowest ever and are likely to rise in the near future. Further advantages of the purchased power are:—

(a) Flexibility in operation; any department may work extra time, independently of the others, without wastage in power;

(b) Saving in land rent and taxes, which are heavy in Bombay".

The Coimbatore correspondent of 'The Times of India' dated March 30, 1937 writes:—

"The construction of the Mukurti Reservoir to supplement water supply to Pykara is nearing completion, while the provision of an additional pipeline for over a length of 10000 ft. and a fourth turbine is being pushed through. The Mettur hydel scheme will be completed and all the three turbines will be put into operation in October of this year. The first turbine will deliver power by about May 15. The entire transmission lines from Mettur to Erode and thence to Singarappet and to Tirupattur, Jalarpet, Vellore, Chittoor,

Villupuram, Tiruvannamalai and *other places* have been completed. The total weight of each generator and its fittings is 165 tons, while each transformer weighs 93, 200 lbs.

The investigation of the Lammasinghi hydro-electric power scheme and the bore-hole scheme for the Ceded Districts are in various stages of progress. Further investigation of the Papanasam hydro-electric scheme in the Tinnevelly District is being made." The same Paper in its issue for March 26, 1937 notes as follows:— "In one of his recent lectures on water power at the University of London, Mr. Hellstrom expressed the opinion that wooden stave pipe lines are, if properly designed, well worth consideration and if properly maintained, these pipe-lines may have life of 50 years,... if the right material is used in the first instance and it is thoroughly dried and treated as necessary, it will keep in good condition by reason of the constant saturation. Little or no mechanical equipment has to accompany the construction gang." The Indian Forest Research Institute has recently issued a booklet on Indian timbers which those interested in wooden poles and pipe-lines should study. Wood is verily coming into its own again.

The following extract is from a press *communique* issued by the Government of the United Provinces (*Times of India*, April 9, 1937):— "The so-called 'Eastern Grid Project', on the preparation of which Sir Alexander Gibbs and partners are now engaged, comprises the construction of a hydro-electric power station on the Garai river in the Mirzapur district some 34 miles south of Benares, together with the necessary aqueducts and pipe lines and an impounding reservoir on a tributary of the Karamnasa river. It is considered that some 8,000 kW or 11,000 H. P. can be made available from this station. The feasibility of generating a similar quantity of power on the Tons river in the Rewa hills is also under discussion with that State.

Negotiations are also in progress with certain local power companies to secure the mutual exchange of surplus power which will be available from the respective hydro and steam driven stations at certain seasons of the year. Such an interchange of power would reduce the capital outlay and working expenses on both the State and private generating systems, for the benefit of all parties concerned.

The Eastern Project further embraces the construction of transmission lines between Benares and Allahabad, Rewa and Allahabad,

Allahabad and Fatehpur, Allahabad and Fyzabad *via* Partabgarh and Sultanpur, also from Benares to Jaunpur with a branch line to Moghalsarai. The transmission system is being designed to serve not only the larger towns on the routes to the various irrigation pumping stations contemplated on the Ganges, Tons and Gomti rivers but also the rural areas traversed by the lines. Owing to the number of concentrated pumping loads on the system, amounting to some 7,500 kW in all, it is hoped that power can be made available at rates not exceeding those in force on the Western Grid.

In 1931, when rural electrification was initiated on the Ganges canal, there were only 9 branch lines serving private agricultural firms and supplying 177 H. P. with a total annual consumption of 14,000 units. In 1935–36, no less than 235 Zamindars were being supplied with electricity for private farms with a total connected load of 3,201 H. P. while the consumption in that year was 2½ million units in these lines. In addition, negotiations were in progress with 98 other Zamindars who have since been connected. Of this total consumption, about half is utilised for private irrigation pumping from Zamindari tube-wells, 30 per cent. for industrial purposes and 20 per cent. for agricultural processes such as cotton ginning, sugarcane and oil crushing etc. The price of electricity for agricultural purposes in the west is one anna per unit at the motor with a reduction to ½ anna after a certain number of units have been consumed in a particular year.

A proposal is also being explored for supplying current at half price for *gur* making at night and during certain hours of the day when the power at the village transformers is not fully utilised for irrigation."

"A very efficient steam power station is being erected at Chandausi. This will run in parallel with other stations. Cadmium-copper line conductors have been used on the double-circuit lattice-towers for crossing the Ganges, 4250 ft. wide, between Chandausi and Sumera." *BEST Apprentices' Journal*, April 1937.

The Ruby mines of Mogok, U. Burma have a water-power plant of 418 kVA, 205 ft. head and the Kanbauk mines of Tavoy, Burma, of 375 kVA with a head of 2,000 ft.

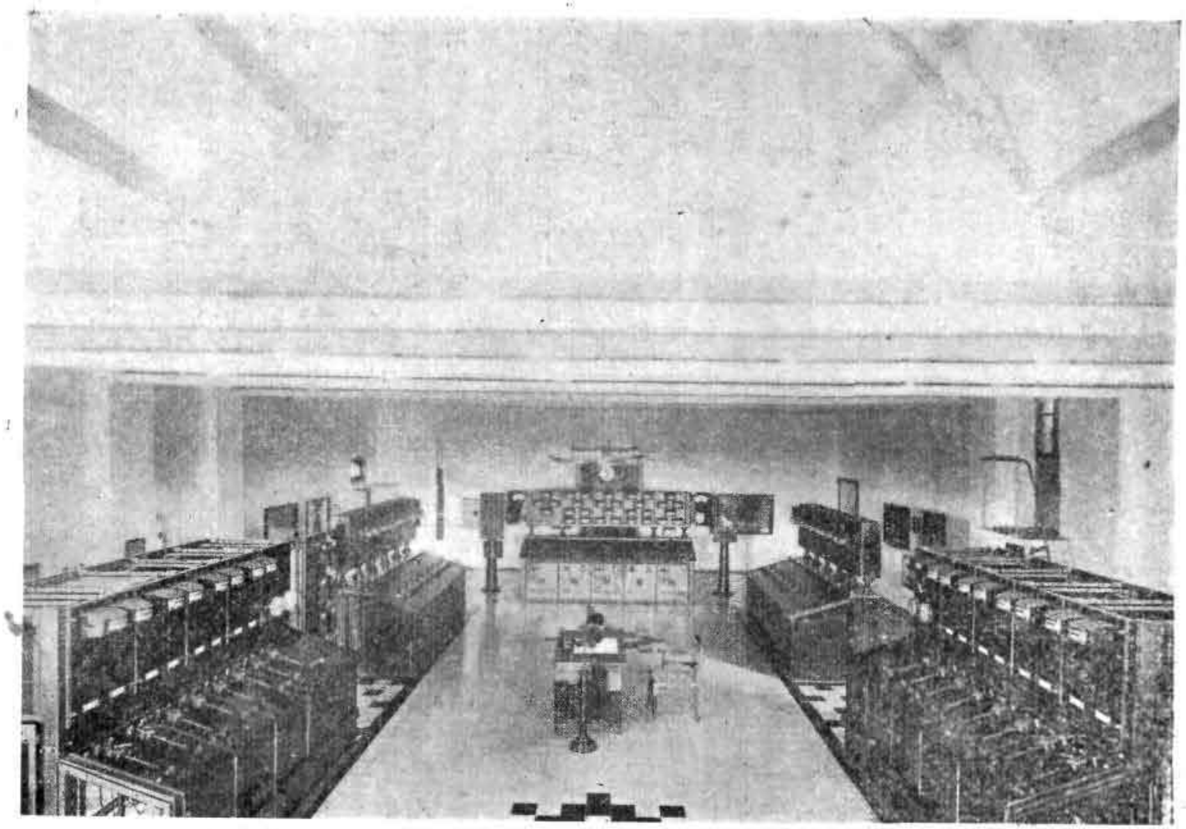


Fig. 39. Remote Control Switchboard Room, Receiving Station, DHARAVI.

APPENDIX I.

Chronological, Geographical and Hydraulic Data.

Year	Name	Source	Situation	Province	Brake Horse-power	Head (Feet)
1897	Darjeeling (Old Plant)	Tributary of Ranjeet & Teesta rivers	6,800 feet in the Himalayas	Bengal	600	275
1917	Do. New Plant	,,	,,	,,	360	650
1900	Kottagudi	Hill stream	Annamalais	Madras	D. C.	700
1932	,,	,,	,,	,,	126	,,
1902	Cauvery Power	Cauvery River	Near the Waterfalls (3000 feet)	Mysore State	6000 e.h.p	406
1904	,,	,,	,,	,,	11000	,,
1907	,,	,,	,,	,,	13000	,,
1914	,,	,,	,,	,,	17000 ,,	,,
1918	,,	,,	,,	,,	21000 ,,	,,
1924	,,	,,	,,	,,	34000 ,,	424
1928	,,	,,	,,	,,	50000 ,,	,,
1933	,,	,,	,,	,,	56000	,,
1904	Cordite Factory	Kateri River	,, (8000 ft.) (Nilgiris)	Madras	890	65
1917	,,	,,	,,	,,	1810	,,
1906	Munnar Valley	Munnar River	Kanan Devan Hills	Travancore	609	400
1924	,,	,,	,,	,,	1170	700
1908–1909	Jhelum Power	Jhelum River	Jhelum Valley (5000 feet)	Kashmir State	7060	400
1909	Jammu	Ranbir Canal,	Jammu City (1200 feet)	,,	1200	[illegible]5
1926	,,	Chenab River	,,	,,	1700	,,
1909	Mussoorree	Bhatta Stream	Himalaya Hill	United Provinces	600	1000
1920		,,	,,	,,	2400	,,
1932	,,	,,	,,	,,	4000	,,

Year	Name	Source	Situation	Province	Brake Horse-Power	Head (Feet)
1913	Simla	Nauti Khad Stream	7000 feet near Sutlej River	Punjab	3,150	540
1914	Gokak Falls	Ghatapra-bha River	Near Water-fall	Bombay	2900	200
1928	"	"	"	"	4700	"
1914	Tata Hydro	*Artificial* Lakes	*2000 feet* Bhore Ghat	"	*66000*	1726
1915	Annally	Hill stream	Annamalais	Madras	180	700
1916	Bhatghar	Yelwandi R.	Dam near Bhor State	Bombay	1400	143 to 70
1917	Bahadrabad	Ganges Canal	Near Hard-war	United Provinces	450	19
1932	"	"	"	"	4000	17
1919	Malakand	Swat R. canal	Khar	N. W. F. Prov.	320	30
1922	Naini Tal	Natural lake	Himalaya Hill	Unit. Prov.	660	1400
1922	Andhra Valley	Andhra and Kasur Rivers	2000 feet Western Ghats	Bombay	66000	1643
1923	Pannimade	Hill Stream	Annamalais	Madras	130	70
1927	Tata Power	Nila-Mula R.	Western Ghats	Bombay	135000	1650
1930	Bhola Falls	Ganges Canal	Near Meerut	Unit. Prov.	2000	14
1930	Palra "	"	" Khurja	"	900	8
1932	Sumera "	"	" Aligarh	"	2000	8
1933	Mandi or Uhl River	Uhl R. and Lambadag R.	6000 feet Himalayas	The Punjab	68000	1800
1933	Pykara	Pykara R. & Glen Morgan R.	7000 feet Nilgiris	Madras	31,500	3080
1935	Satara	Urmodi R.	Kas tank	Bombay	150	538
1935	Mettur	Cauvery R.	Dam, near Salem	Madras	33000	125
1937	Pallivassal	Munnar R.	Waterfall	Travancore	14000	1880
1939?	Periyar	River	Near Madura and Travancore	Madras	21000	"

APPENDIX II.

Particulars of Proprietorship and Electrical Features.

Name	Proprietor	Generating Station	Kilowatts	Alternator		Transmission Line		Remarks
				Cycles per second	Volts	Volts (Max.)	Max. Distance (miles)	
Darjeeling I	Municipality	Darjeeling	400	83.3	2330	2330	6	
,, II	,,	,,	250	,,	,,	,,	...	
Kottagudi	Kanan Devan Co.	Kottagudi	...	...	500	500	...	D. C. plant
Cauvery Falls	Mysore State	Sivasamudram	37500	25	2200	78000	150	
Cordite Factory Kateri Falls	Govt. of India Ordnance Dept.	Aruvankadu	1000	40	5000	5000	3	
Munnar	Hill Produce Co.	Munnar in Travancore	1000	50	2200	11000	22	For tea estates
Jhelum Power	Jammu & Kashmir State	Mohora	4000	25	2300	30000	100	For all places in Kashmir
Jammu	,,	Jammu	1072	50	3300	3000	5	
Mussoorree	Municipality	Mussoorree	3000	,,	400	6600	30	Also for Debra Dun
Simla	,,	Chaba	1750	,,	2200	15000	,,	
Gokak Falls	Company	Gokak Falls	2600	,,	460	460	0.5	For cotton mill
Tata Hydro	,,	Khopoli	48000	,,	5000	100000 22000	250	Tied with Bhira and Bhivpuri
Annally	,,	Annally	140	,,	2200	2200	6	
Bhatghar	Govt. of Bombay	Bhatghar Dam	1024	,,	2000	2000	1	
Naini-Tal	Municipality	Naini-Tal	450	,,	3500	3300	2	
Bahadrabad	Govt. of ,, U. P.	Bahadrabad	2400	,,	6600	37500	380	Tied with Bhola etc.

Name	Proprietor	Generating Station	Kilowatts	Alternator		Transmission Line		Remarks
				Cycles per second	Volts	Volts (Max.)	Max. Distance (miles)	
Pannimade	Kanan Devan Co.	Pannimade	100	50	2200	2200	5	
Andhra Valley	Company	Bhivpuri	48000	,,	5000	100000	,,	Tied with Khopoli & Bhira
Tata Power	,,	Bhira	87000	,,	11000	110000	,,	Tied with Khopoli & Bhivpuri
Bhola	Govt. of U. P.	Bhola Falls	200	,,	400	37500	,,	Tied with Bahadrabad
Palra	,, ,,	Palra ,,	500	,,	,,	,,	,,	
Sumera	,, ,,	Sumera,,	1200	,,	,,	,,	,,	
Kottagudi	Kanan Devan Co.	Kottagudi	100	,,	440	2200 33000 66000	2½ miles 48 139	Ropeway
Mandi or Uh River	Govt of Punjab	Jogindra Nagar	48000	,,	11000	132000	213	
Pykara	Govt. of Madras	Singara	18750	,,	,,	66000	110	

Low pressure used for distribution of power is SINGLE PHASE 250 Volts for lights and domestic appliances and three-phase 400 Volts for motors. Rates for the former are 4 to 6 annas, and for the latter a half or a third as much. Lower still are the rates for heating, agricultural appliances and irrigation pumping. For off-periods and large consumers, specially reduced rates (often on a sliding scale) are quoted. Instead of meter rates, flat rates are charged in some places from those who prefer the latter. Besides a charge for energy consumed, a charge for Kilowatts installed or for maximum demand is made by several Supply Companies.

Please see H. E. I. I. page 250 and 251 for other data, facts and figures.

APPENDIX III.

COSTS OF HYDRO-ELECTRIC SCHEMES.

(Extracts from ' Journal of Association of Engineers' for June 1933).

1. *Pykara* River Scheme.

The works cost £ 900,000 which is well within the estimated cost. (126 lakhs of rupees approximately).

2. *Mandi* (Uhl River) Scheme.

	Estimated in Lakhs of Rs. (year, 1925–1930)	
Production	158	245
Transmission	181	228
General charges	24	127
Extensions to Supply System	20	20
Local Distribution	18	17
Mill Conversion	8	8
Total	449	645

The final figures are not yet available.

3. *Mettur* (Dam) Project.

This will utilise a head of 125 feet and develop 33,000 horse-power costing about Rs. 1,30,00,000. (Rs. 130 lakhs).

4. *Periyar* (River) Scheme.

It is expected to be begun in 1936 and estimated to cost about Rs. 1,80,00,000. (Rs. 180 lakhs).

(Extracts from 'Indian Engineering,' Apr. 23, 1932).

5. U. P. Ganges Canal Scheme.

The present project provides 13,000 h. p. (hydro-electric) and 2500 h. p. of oil engine reserve at a cost of Rs. 1,38,000. ('The Times of India' gives the figure of Rs. 142 lakhs).

From the same paper have been culled the following figures :—

6. *Pallivassal* (Travancore State) Scheme.

Total estimated cost Rs. 70.8 lakhs. (10,000 kilovolt-amperes).

7. *Cauvery Falls* Installation, Rs. 285 lakhs, approximately, excluding cost of Krishnarajasagara Works.

Mysore State Rural Electrification schemes, Rs. 19 lakhs, including small towns, already electrified.

8. *Tata plants*—Rs. 1567 lakhs.

N. B. For costs of hydraulic development of other Indian Hydro-electric Installations, see H. E. I. I. particularly page 251 and Table 47.

APPENDIX IV.

GROSS REVENUES OF ELECTRICITY UNDERTAKINGS.

(*Culled from Reports of Engineers or Managers*).

1. Electrical Department of the Government of Mysore (Hydro-electric).

1926–27	41.24 Lakhs of Rupees
1927–28	41·29 ,,
1928–29	43·45 ,,
1929–30	47·45 ,,
1930–31	50·41 ,,
1931–32	50·33 ,,
1932–33	52·30 ,,
1935–36	58·52 ,,

2. Tata *Hydro-Electric* Companies of Bombay.

	Hydro	Andhra	Power
1927–28	45·43	52·30	35·35 Lakhs.
1928–29	40·64	48·70	44·11 ,,
1929–30	45·80	55·44	55·14 ,,
1930–31	47·97	53·56	54·96 ,,
1931–32	48·06	62·31	57·01 ,,
1932–33	50·54	56·34	52·75 ,,
1933–34	37·97	54·77	57·64 ,,
1934–35	50·15	55·69	73·05 ,,

3. Mussoorree Electricity and Water Supply Undertaking (Hydro-electric).

1931–32 4·44 Lakhs of Rupees.

4. Ganges Canal Installations (Hydro-electric)

1932–33	10 lakhs
1933–34	15 ,, (estimated)
1934–35	16·5 ,, ,,
1932–33	28000 rupees rural electrification (*actual*).

5. Mandi (Uhl River) Scheme (Hydro-electric).

1945 61 lakhs (estimated)

6. Pykara Hydro-Electric Scheme.

1933–34 5 lakhs

7. Madras Electric Supply Company (Steam).

1928 1·69 lakhs.

8. Cawnpore Electric Supply Co. (Steam).

1928 1·34 lakhs of rupees.

N. B. It appears from the Report for 1928 of the Mysore State Electrical Engineer that the ratio of working expenses to gross revenue for the Tata, Mysore, Madras and Cawnpore schemes is 25.90, 22.65, 40.52 and 39.74 per cent respectively. The inference is obvious. In the case of Mysore, this ratio was reduced to 21.34 for the year 1931–32 and further reduced to 20,86 for the year 1932–33.

APPENDIX V.

THYRITE ARRESTER.

Of recent years, the Thyrite Lightning Arrester is being very largely used in Power Stations, and has replaced older types described in the Author's booklet No. III on Lightning, Lightning Conductors, Protectors and Arresters published in 1924. It is therefore thought desirable to present the reader with the following extracts from a Bulletin of the manufacturers, the G. E. Co. of Schenectady, N. Y. U. S. A. "Thyrite is a dense homogeneous inorganic compound of a ceramic nature perfectly stable and mechanically strong. The Thyrite arrester has no time lag. This characteristic is common to both lightning and system voltages. It involves no maintenance expense. Thyrite possesses the remarkable characteristic of being substantially an insulator at one voltage and becoming an excellent conductor at a higher voltage. The resistance decreases and the current increases 12·6 times whenever the voltage is doubled. The arrester is made in disks sprayed with metal on both sides to provide contact surface. Each disk is 6 inches in diameter and $\frac{3}{4}$ inch thick, has an active area of 28 sq. in. and a volume of 21 cu. in. Each disk is rated approximately 1 kV (r. m s.) at system frequency, and the flash over distance of $\frac{3}{4}$ in. per kV of rating is sufficiently liberal to permit the Thyrite to discharge several thousand amperes without the slightest tendency to flash over the outside edge. Thyrite will not puncture or shatter when subjected to the most severe discharges. The standard unit is rated 11·5 kV r.m.s. so that it consists of 11 disks in series with a gap assembly, all housed in a glazed wet-process porcelain container. The unit is fitted with top and bottom castings of heat-treated aluminium. The gap assembly is placed at the bottom of the unit with cushion contacts at top and bottom, providing pressure connection. The wet-process porcelains used in the gap assembly are cushioned and gasketed. A sturdy triple-spring assembly between the top casting and stack of Thyrite disks exerts a constant pressure.

The standard unit is 13 in. in diameter and 15 in. high and weighs 100 lbs. net. Its porcelain housing has a liberal external 60-cycle flashover r. m. s. voltage of 110 kV dry and 70 kV wet. The ultimate cantilever strength of the unit is 4300 lbs., the ultimate strength in tension 7000 lbs and in compression 5000 lbs.

The units are assembled together by bolts inserted in holes in the top casing and threaded in the bottom casting of the adjacent unit. The arrester requires the grading ring for improving voltage distribution for 115 kV and above. The grading ring is made of hot-dip galvanized pipe attached to the top unit and it extends down concentrically around a few arrester units."

Thyrite arresters have been installed at the new Tata stations including the Poona receiving station. Thyrite arresters have replaced the aluminium electrolytic arresters at the Cauvery Power Installations of Mysore State. They are particularly welcome in outdoor stations which are likely to be the vogue in future installations even for high voltage stations and substations, judging from recent hydro-electric plants described in earlier chapters of this book.

Other kinds of lightning arresters are described in the Author's Booklet No. III on '*Lightning, Lightning Conductors, Protectors and Arresters*'.

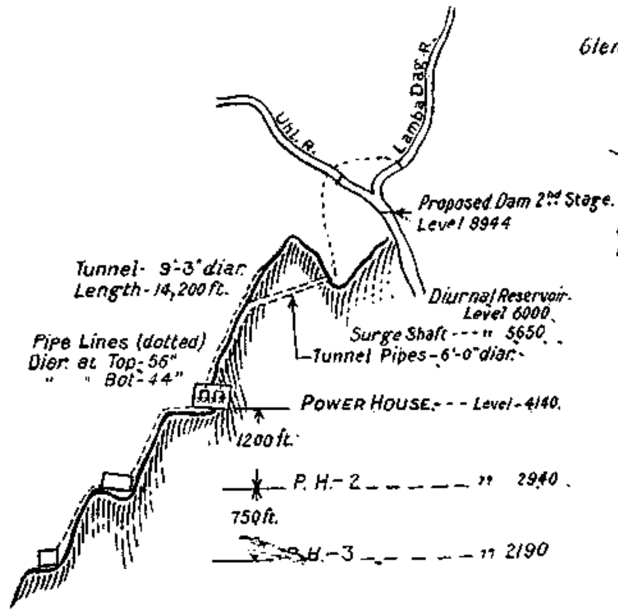
APPENDIX VI.

ELECTRO-CHEMICAL INDUSTRIES.

According to C. P. Steinmetz, the Author's professor at Union College at Schenectady, N. Y., U. S. A., the main branches of electro-chemical work are (1) electrolytic, e. g. electrolysis of alumina, and (2) electro-metallurgical, in which the heat effect of the current produces chemical action, e. g. heating of lime and carbon in an electric furnace to produce calcium carbide which with atmospheric nitrogen provides cyanamide for manures, dyes etc. Though wide and varied use has been made of water power, it has not been utilised in India on any appreciable scale for making fertilisers or for other electro-chemical work. The Indian Industrial Commission expected, to use the words of their Report, that hydro-electric energy would be employed for" electro-chemical industries such as the extraction of aluminium from bauxite and the manufacture of nitrogen compounds from the air. Large amounts of water power are in commercial use in other parts of the world for the manufacture of iron, steel, alloys, aluminium, calcium carbide and various nitrogen compounds. It is imperative that some, if not all, of these industries should be established in India". A small beginning was to have been made in Kolhapur State where a hydro-electric plant was to furnish power for the manufacture of aluminium. At present, 'the Indian manufacturers of aluminium utensils have to manufacture out of raw materials imported from foreign countries.' *Progressive India, April 1933.* On pages 109, 110 and 111 of '*Hydro-electric Installations of India*', there are given lists and tables of electro-chemical industries, with particular reference to India and the interested reader would do well refer to that book.

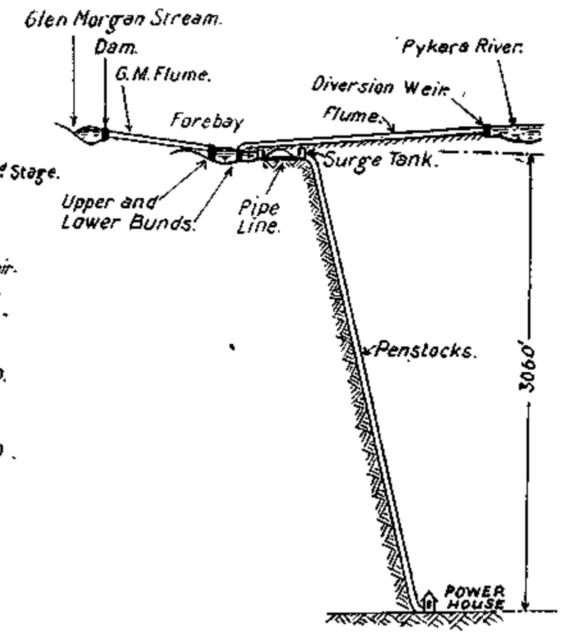
Though not of immediate interest, the following quotation points out a possible outlet for hydro-electric energy at a future date:-"In the future, if electric power is made cheaper and electrolysis is used as a commercial source of hydrogen and oxygen, the residue can be worked up for *heavy* water as a valuable by-product". *Faraday House Journal*, No. 6, 1934. Heavy water contains diplogen, besides oxygen and hydrogen. With diplogen, new sugars, oils and drugs may possibly be prepared, leading to new industries of an electro-chemical character.

Reference may be made to the extract from the Sept. 1933 issue of the *Electrician* "hydrogen produced hydro-electrically which already pays can be used to hydrate coal and produce valuable liquid fuels," and to the facts and figures given in Chapter V, as both these pertain to electro-chemical processes. Readers interested in Aluminium may consult the article on this topic in '*Indian Engineering*' for Aug. 11, 1934.



MANDI HYDRO-ELECTRIC SCHEME.
Transverse Section

Figure No. 31 (To face page 112)



PROFILE SECTION, PYKARA SCHEME.

Figure No. 32

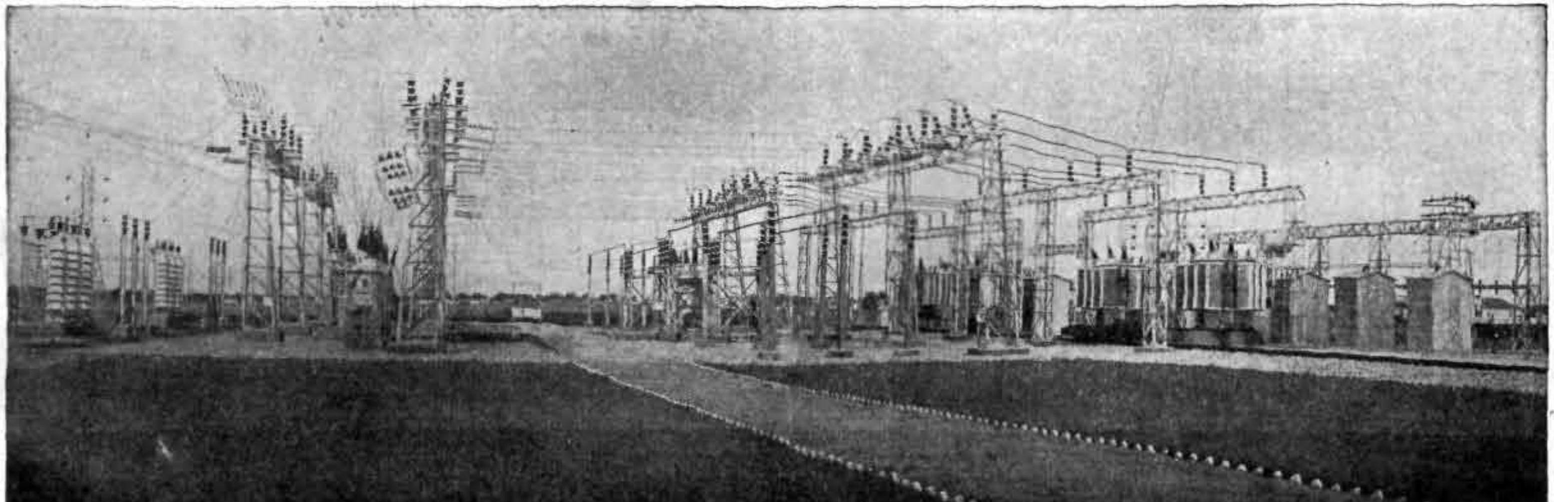


Fig. No. 38. Outdoor Receiving Station, Coimbatore, Madras Presidency.

INDEX

Latest Information.

Mysore Electrification. Total expenditure on combined hydro-electric and irrigation works to the end of the year was Rs. 763,00,000. Net revenue from the combined Schemes was Rs. 40 lakhs or 5·2% on the combined outlay.

Ganges Canal Scheme. The total consumption has risen from 14,000 units to 2,500,000 units within the last 5 years; of this, half is utilised for private irrigation pumping from Zamindari tube-wells, 30% for industrial purposes and 20% for agricultural processes, such as cotton ginning, sugarcane & oil crushing. The Fyzabad project will make available 8000 Kilowatts. A similar scheme is the subject of negotiation between the Government and the Rewa Durbar.

Rampur State Tube-well Scheme. Electricity is being generated by Ganges water falling 15 feet at Salawa at a distance of nearly 200 miles. On its way to Rampur, more than a thousand village pumping installations are worked by the electric current. At Rampur, the electricity is utilised for lifting water for irrigation from the vast reservoir which exists at a depth of 15 ft. below the fields. (*Indian Engineering*, April 1937)

The same monthly for May says that there is a proposal to amalgamate the three electric supply concerns in Delhi into one and take the power required from the Punjab Hydro-electric system, if available.

OPINIONS ON BOOKS

WRITTEN BY

PROFESSOR SHIV NARAYAN, I. E. S., M. I. E. E. (Lond.), F. R. S. A.
Member A. I. E. E. (U. S. A.), M. I. E. (Ind.), B. E., M. Sc., M. A., B. Sc.,

"HYDRO-ELECTRIC INSTALLATIONS OF INDIA."

A Treatise for the use of Students, Engineers, Industrialists and others.

Mr. S. Sarkar, B. Sc. (Eng.)—a younger member of the profession not acquainted with the Author writes :—

I have just gone through your excellent handbook 'Hydro-electric Installations of India' and I take this opportunity to convey to you my heartfelt thanks for putting before me in a nutshell the hydro-electric position of India.

The difficulty experienced by hydro-electric students in India arises from two factors :—

(1) There is no central department in India which deals with this subject. Since the Montford reforms, this subject has been transferred to the Provinces and as such it has lost much of coherence...

(2) There is no hydro-electric journal in India which can do the same work in absence of a Govt. Dept.

Hydro-electric students have therefore no option than to fall entirely on such painstaking work of Authors as you are.

I shall crave your indulgence in this letter if you can kindly give me the following information :—

(1) If you have revised your book since 1922 and brought it up-to-date. (2) If not, will you kindly give me a list of Hydro-electric stations that have come into operation since 1922 and stations under construction.

A brief outline with principal features of stations will be very welcome as it would undoubtedly help me in the pursuit of the study of further details.

N. B. A new book *Indian Water Power Plants* has been published.

Sir Sydney Crookshank, Secretary to Government of India, Public Works Dept., Simla.

It is an interesting and instructive production on which I congratulate you. I read it with great interest.

Mr. Venkatarao, Siragola Farm.

I will never repent having paid for the book as all the information about Hydro-Electricity is beautifully epitomised in it. It is a book worth having.

"Industry", Calcutta.

The public owes a deep sense of gratitude to Professor Shiv Narayan for his very timely appearance with a decent manual, even a glance on the contents of which will show it to be undoubtedly a

work of authority on the subject. In this book of reference, hydro-electric plants have been explained; working of equipments has been elucidated; future projects have been exhaustively treated; economic factors of electric installations have been given; besides copious illustrations, statistical tables, glossary of technical terms etc.

Principal, College of Engineering, Poona.

Mr. Shiv Narayan has written a most readable and instructive book which certainly fills a want in Indian technical literature. As a book of reference, it is of great value, giving as it does, useful data regarding existing and proposed Hydro-Electric Schemes in India and the accounts of these works which are given are written in a manner both lucid and interesting. The simple explanations and examples of fundamental theory which are given should be valuable to students and to capitalists desiring to understand broad principles. An excellent book.

"Indian Industries and Power," Bombay.

The book comes very opportune at the present moment and we have no doubt will be well received by all those who are interested in the industrial progress of India generally and in hydro-electrics particularly.

Executive Engineer, Public Works Department and Professor of Civil Engineering.

A very handy volume, giving a bird's eye-view of the development of Hydro-Electric Works up to date in India. Of much interest to students as well as to businessmen engaged in this department of engineering......written in an easy, simple and readable style, with information as full as one would wish on each work described.

Director of Agriculture, Bombay Presidency.

Very many thanks indeed......I hope the book will be a very great success.

So also wrote the **Director,** Indian Institute of Science, Bangalore.

Chief Electrical Engineer, Kashmir and Jammu.

Congratulate you upon your articles upon the Jhelum Power Installation and Electric Dredging etc.

Rao Sahib G. Sundaram of Madras.

I have great praise for you for the time and trouble you have taken regarding this book and your success in condensing into it a really mighty mass of information. I am sure your second book will be as valuable an addition to an engineer's library. I request you to register my name for it.

N. B. The second book has been published under the title of *Indian Water Power Plants.*

An Engineer in France.

Congratulate you on the Volume of Information.

Engineer, Lighting Department, G.E. Co., Schenectady, N. Y., U. S. A.

We are keeping a volume of your book in this Department as a Valuable Record of the Indian Electrical Installations.

"Times of India, Engineering Supplement."

HYDRO-ELECTRICS.

Shiv Narayan's New Book.

The technical literature of India has received a valuable addition in Professor Shiv Narayan's new book, "Hydro-Electric Installations of India."

As is well known to the majority of engineers in India, Mr. Shiv Narayan is a Professor at the Poona College of Engineering and for many years he has assiduously studied the science of hydro-electricity, his experience in this direction including several valuable years which he spent in the United States of America (and in the Kashmir State). He has also contributed many articles upon this subject to this Supplement and to other technical publications in India, and has thus earned a place in the select little coterie of publicists who have made the study of hydro-electrics peculiarly their own.

Mr. Shiv Narayan does not claim to advance any new theories in his book but rather to summarise the past history of hydro-electrics in India, to review the present position and to discuss something of its future in India as compared with other countries of the world; and that *he has succeeded in weaving dry-as-dust facts and figures into a thoroughly interesting and informative story is no small triumph in itself.* Actually, however, the Author has gone farther than that, for he has incorporated in his book a mass of information which for lack of a better term may be called "other peoples' views." The result is that the student, for whom the book is primarily intended, is provided with a valuable summary of leading engineers' views concerning the various hydro-electric installations in India but also with chapter and verse for *many weighty opinions* which had an important bearing upon modifications and changes in design in other works of a similar nature.

In the first two chapters of his book, Mr. Shiv Narayan discusses the general principles of hydro-electric engineering and quotes a few essential formulæ which are illustrated by means of examples from installations in various parts of the country. With these preliminaries, upon which he does not devote any unnecessary space, the author comes to his subject proper and in the course of twelve chapters he describes the main features of every hydro-electric installation in the country, both in British India and in the Native States. There follow six chapters in the course of which the author discusses the economic problems of electric installations and gives a large number of statistical tables and other technical information and the book

concludes with a chapter devoted to matters which became topical whilst the remainder of the book was in Press.

(Hydro-Electric Installations of India, by Professor Shiv Narayan, B. E., M. Sc., (U. S. A.), Member. A. I. E. E., A. M. I. E. E. (London), A. M. I. E., (India) College of Engineering, Poona. 302 pages with many illustrations...Price, cloth Rs. **9**, quarter cloth Rs. **7–8**, paper cover Rs. **6–8**.

N. B. The price of *Indian Water Power Plants* is Rupees Five only.

Superintending Engineer, India's Largest Hydro-Electric Scheme.

I have just finished your book on Hydro-Electrics in India and congratulate you on your successful enterprise. It is a mine of information and should spur the great Indian capitalists to beautify their great country with fine lakes and large industries.......I have had much experience of Native States where money is plentiful and consider that your handbook should be carefully studied by the Ruling Chiefs and their Dewans...I hope you will soon be thinking of a second edition."

N.B. A new book, supplementing the information given in the first book, has been issued under the name of *Indian Water Power Plants.*

Superintending Engineer, Electric Company, Bombay.

A most useful compilation......

Professor of Electrical Engineering, University of Nebraska, U. S. A.

Very interesting to know what the developments are and what the latent possibilities may be.

Professor of Electrical Engineering, Sibpur.

This great book on Hydro-Electric Engineering.........very interesting.

Executive Engineer, Gwalior, Central India.

"......read your book......It is well-written and lucid......"

Late Principal, College of Engineering, Poona.

I have seen the manuscript of this book. It has been written and revised after considerable correspondence with engineers and officers in charge of the various installations described. The book is likely to be of considerable use to various Government officers especially to those in the Public Works Department and Industries Department and to teachers in Indian Engineering Colleges.

LATE MINISTER OF EDUCATION, BOMBAY.

Many thanks for your book. I cursorily went through it and found it very instructive.

5

Managing Director, Jost's Engineering Company.
Find it interesting.

S. K. Gurtu, M. I. C. E., Engineer-in-Chief, wrote in an issue of **"Indian Engineering"** :—

"Professor Shiv Narayan has not only described in his book the different Hydro-Electric Installations of India, giving their salient points and special features, but has gradually built up principles of designing and drawing up specifications which will prove extremely useful to many engineers, who though not electricians have yet, in the exercise of their functions as Heads of Engineering Departments, to deal with hydro-electric schemes.

Professor Shiv Narayan's book will also help in drawing the attention of the authorities to the fact that if black coal is showing signs of exhaustion or cannot keep pace with the demand for it, white coal is lying scattered in profusion all over the continent of India and if properly exploited would give millions of horse-power...... in spite of so many possibilities of water-power development, few Governments have thought seriously of it......it may be hoped that Professor Narayan's book will interest them in water-power enterprises and induce them to develop this new source of power.

Professor Shiv Narayan's book while it provides pabulum for a trained electrician, is replete with notes and explanations which make the subject intelligible to everybody interested in the question of exploiting the new sources of power, whether as a Civil Engineer dealing with water-power schemes or as a financier desirous of examining for himself the merits of a scheme put forward before opening the purse strings; *e. g.*, the 'Economic problems of electric installations,' the illuminating notes on diversity and load factors, voltage, etc.

The Professor not only draws attention to the numerous problems relating to the development of water-power but gives formulæ and calculations and shows their applications......a matter of utmost importance in the present state of general ignorance about this subject......

Engineering Editor, "Times of India," Bombay.

I must take an early opportunity of congratulating you upon the *very comprehensive* manner in which you have dealt with your subject...There *has long been a need for such a book*, both for students in India and as a work of reference......I sincerely hope that it will soon run to a second edition......(This and the Review of March 17 reproduced above were both written after the Government publication, Triennial Report on Water-Power, had been reviewed by the "Times of India").

N. B. The new book supplementing the first has been named *Indian Water Power Plants* and priced Rs. 5 only.

"Indian And Eastern Engineer", Calcutta, while announcing the book before publication:—

Mr. Shiv Narayan's experience of his subject has been *highly practical*, both in the West and in the East and this combined with a

distinctly literary bent ensures that his book will be of an *eminently readable* character while based upon practical knowledge: a combination which is not always found in 'Professors'. At the present time, a work on the "Hydro-Electric Installations of India should be *of wide utility......*"

The "**Indian Textile Journal**", Bombay, April 1922.

The book is indispensable to engineers who desire to be up to date with the electrical undertakings and enterprises of this country. We commend the book to the notice of all who are interested in this subject.

Proceedings of American Society of Civil Engineers and Journal of American Institute of Electrical Engineers

This book presents in popular form the principal facts concerning the hydro-electric plants and projects of India. It also explains the hydraulic and electrical principles involved, the general design and installation of plants and the economic factors to be considered. The work is intended to direct attention to the water-power resources of the country and to serve as a guide to engineers and capitalists interested in utilisation of them.

"**Forman Christian College Monthly**" Lahore, March 1923.

This is a students' book, intended mainly for students of technical schools and engineering colleges; the author has struck a happy medium between the theoretical and practical sides of the subject. The fundamental principles and outlines are well handled and the standard hydro-electric plants are logically developed. The book is directed towards the design and performance aspect of the subject rather than to the mathematical aspect, although it carries a sufficiency of relevant "Formulæ and examples" where necessary, to make it a self-contained and useful book. The first part is introductory and contains an account of the installations at Jhelum, Jammu, Bombay and Bhatghar; the second part deals with the Cauvery falls, Simla, Malakand Installations and the projects of Indian States. The third part contains an account of the Economic Problems, Power Transmission and Selection of Sites. The fourth part is more or less an appendix giving some useful definitions, standards and latest information. The text is very readable.

ELECTRICAL ENGINEERING BOOKLETS (Re. 1/-each).

Booklets { **III.—Lightning. Lightning Conductors, Protectors and Arresters. I. —Electric Generators, Motors and Circuits.**

"**Indian And Eastern Engineer**", November 1923.

This book of facts, figures and formulæ, written by Mr. Shiv Narayan, Professor of Electrical Engineering and Physics, Thomason College, Roorkee, is specially intended for the use of Indian students and engineers.

Professor Shiv Narayan is the author of several well-known text-books on electrical engineering, and **Electric Generators, Motors and Circuits** is the first of a new series of electrical engineering booklets which he intends publishing.

These booklets comprise, in the main, some of the author's casual contributions to various technical journals, one of the chief being **The Indian and Eastern Engineer**, and if they all prove as successful as the first of the series, *they should become standard works for the use of students in the various engineering colleges of India*

Principal and Professor of Physics, Government College, Lahore.

I acknowledge with thanks receipt of your booklet on **Electric Generators, Motors and Circuits**. *It is well-illustrated, considering the price of the book and it should prove very useful to students preparing for examinations.*

"Indian Engineering," Calcutta, October 6th, 1923.

This little volume containing important facts, figures and formulæ written with particular reference to Indian conditions, as far as the technical character of the subject permits, giving an intelligent explanation of the essential facts and figures in a compact and clear form and indicating the directions in which the information imparted would probably be of assistance in later study or in practical life. *It can be studied with advantage by Indian students, engineers and industrialists and those interested in electrical engineering science and progress*......series of booklets represents the author's private study and research undertaken for his own sake and that of other students. Mr. **Shiv Narayan's** *publication ought to meet with a wide demand.*

Principal, V. D. J. H. Technical Institute, Lahore.

Your booklet is a welcome addition to the Institute Library, as it is a help to those possessing a slight knowledge of the subject.

"Industry", December 1923.

Professor Shiv Narayan has built up a reputation for himself as the author of several practical treatises (on hydro-electric engineering). *All his works are marked by lucidity and conciseness and are amply illustrated.* The book under review deals with different kinds of generators and motors; the mechanism of dynamos; the laws of current in the circuits and allied items. The subject *is clearly expounded and elucidated with facts, figures and formulæ.*

Late Professor of Electrical Engineering, College of Engineering, Poona.

I have looked through the booklet. It *is useful to students* inasmuch as it collects together in a concise form the fundamental facts and figures which every student is expected to know......deals with the most important matter of the subject.

Professor of Electrical Technology, Indian Iustitute of Science, Bangalore.

I think, the book on Lightning Protection should prove valuable.

Indian Engineering, February 16th, 1924.

Lightning.—This is the third of a series of Electrical Engineering Booklets dealing with the erection and testing of Lightning Conductors. How to guard buildings and machines, telegraph and transmission lines and systems.

The author's aim has been to give an intelligent explanation of the essential facts and figures in a compact and clear form, with reference to Indian conditions so far as the technical character of the subject permits. *In this, Mr. Shiv Narayan has been very successful and technical students and engineers will find the booklet most useful, The work contains up-to-date information and illustrations.*

'Journal of the American Institute of Electrical Engineers,' 'Proceedings of the Amerieau Society of Civil Engineers,' 'Mechanical Engineering' and **'Mining and Metallurgy',** February 1924.

Electric Generators, Motors and Circuits, (32pp., (19) illustrations, diagrams), **Lightning...Conductors, Protectors and Arresters,** (35pp., (17) illustrations, diagrams).

The pamphlets by the Professor of Electrical Engineering and Physics at Thomason College, Roorkee, India, and intended for students and those in search of elementary information on these subjects. The first contains data on direct current generators, motors and circuits; the second describes lightning and the methods in use to protect buildings, machinery and electric lines. The books are not mathematical and the author endeavours to present his information in an interesting way.

Indian and Eastern Engineer, February 1924.

This series of booklets is being designed to meet the need for *suitable* and *inexpensive handbooks* for Indian students of the Engineering profession, and the third volume fulfills its purpose as adequately as its two predecessors. *The text is well written in simple language and the illustrations are both numerous and well executed.*

N. B.—Typewritten copies of booklets not yet out from the Press can be supplied at Re. 0–8–0, *i. e.* half the price for printed copies. The booklets treat of the following subjects:—Electrical Engineering Materials, Pioneers, Education, Alternators and A. C. Motors. *Books in Preparation:—Electric Railways in India; Wireless stations in India.*

Indian Water Power Plants, about 200 pages, 35 illustrations, Price Rs. 5 only, is, like the other books mentioned above,

Obtainable from (1) Messrs. D. B. Taraporewala, Sons & Co., Booksellers, Bombay and (2) Brij Narayan, Esq. of Poona Electric Supply Co., Ganeshkhind Road, Poona 5.